JOURNAL OF SCIENTIFIC INSTRUMENTS

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOLUME V

1928

PUBLISHED BY THE
CAMBRIDGE UNIVERSITY PRESS
LONDON: *Fetter Lane*, E.C. 4

PRINTED IN GREAT BRITAIN

CONTENTS OF VOLUME V

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V   JANUARY, 1928   NO. 1

A NEW UNIVERSAL LONG-WAVE RADIO INTENSITY MEASURING SET.

BY J. HOLLINGWORTH, of the National Physical Laboratory. (Communicated by permission of the Radio Research Board.)

[*MS. received, 15th October*, 1927.]

ABSTRACT. In this paper it is pointed out that the existing long-wave measuring apparatus has been found not sufficiently refined for the more complicated observations now required in the study of the polarization of radio waves; and a detailed description is given of a new apparatus for the purpose, which is primarily designed to measure in rapid succession the E.M.F.'s in two coils oriented in different directions to the arriving signal, and the phase angle between these two E.M.F.'s.

IN a previous paper* the author has given a description of a piece of apparatus for the measurement of the received intensity of long wave-length (5000–30,000 metres) radio signals. This set has been in use for several years; but recently, due to the increase of knowledge on the subject, the need has been felt for apparatus on similar lines capable of making more elaborate observations.

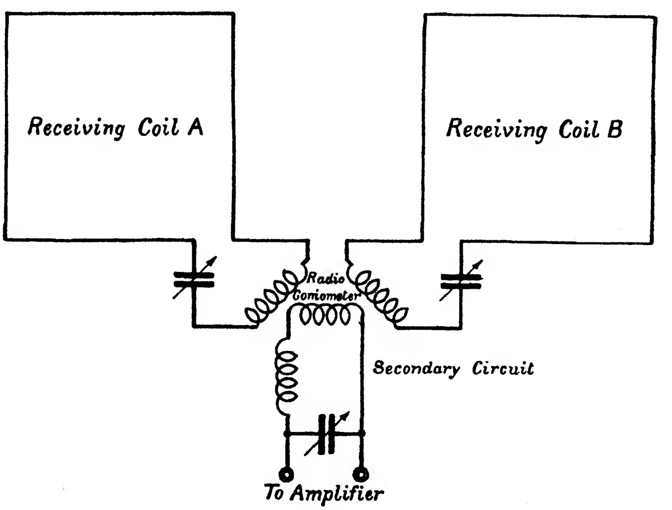


Fig. 1. Phase Measurement—Diagram of Principle Involved

It has been found that at medium distances (< 1000 km.) the received signal does not consist of a single free wave, but of a combination of several, some of which have been refracted with complex polarization from the conducting layer in the upper atmosphere. For further progress, some analysis of these seems to be essential; and, though such analysis can

* *Journ. I.E.E.* 61 No 317.

in theory be carried out on any ordinary receiving set, the results are not good; and a specially designed set is necessary for satisfactory working.

Such a complex system of waves involves four variables—the intensities of the two components of polarization and their phase relations relative to the ground wave, the intensity of the last being calculable at these wave-lengths. By assuming plane polarization these unknowns can be reduced to three, and there is considerable indirect evidence that in certain cases this is justifiable; though direct experimental proof is not always possible.

Hence the set must be capable of taking three or four different observations in rapid succession. The variations which occur on long waves do not appear to be as rapid as on short waves, so that absolutely simultaneous observations are not essential; and in this set the whole series can be taken in half a minute. On the assumption of plane polarization the three observations resolve into three intensity measurements at different orientations of the receiving coil or their electrical equivalents. Actual experience has shown that the most convenient ones are the E.M.F.'s induced in two equal vertical coils set at 45° on either side of the actual direction of the transmitter, and the phase angle between these E.M.F.'s. A fourth measurement with these coils would lead to no new equation, and as the system of wave-length change employed by Appleton* is impracticable on long waves, use is made of a vertical aerial in combination with one of the coils as described in detail later.

Unfortunately this observation depends on the cosine of the angle of incidence of the down-coming waves, so that it yields no result unless θ is small, *i.e.* the transmitter not far distant. There appears no way out of this dilemma.

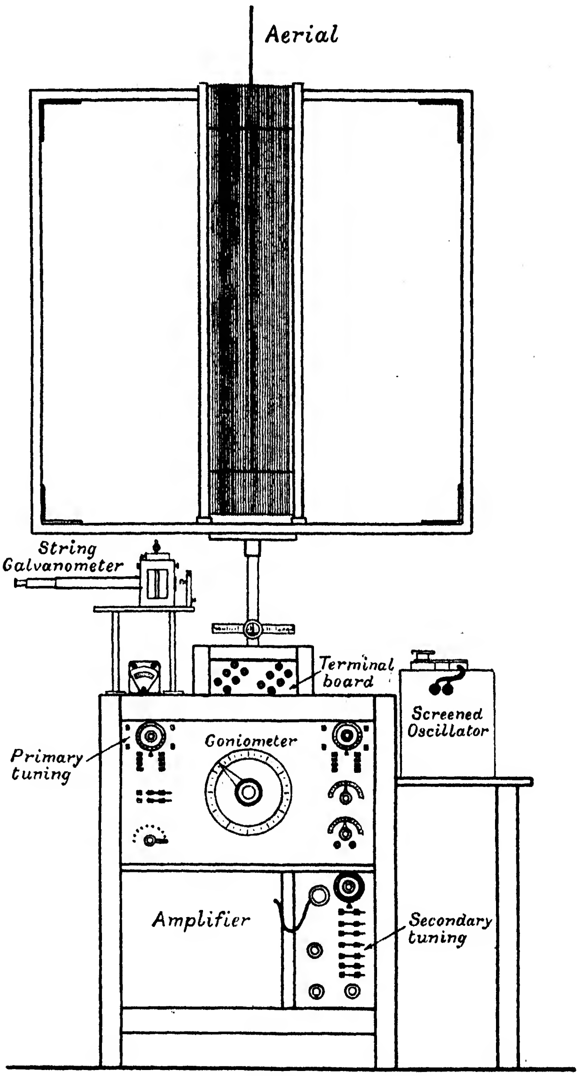


Fig. 2

Principles Involved

As will be explained later, the method of intensity measurement is closely similar to that employed in the original set.

For the phase measurement the system adopted is shown in Fig. 1. The two equal receiving coils are tuned and passed through the two fixed coils of a radiogoniometer of standard type; the search coil being in a tuned secondary circuit connected to an amplifier with the standard detecting and calibrating devices. Now if the E.M.F.'s in the two coils are in phase, a sharp minimum will be obtained on the goniometer. If they are out of phase, this minimum will be blurred; but by slightly detuning one circuit they can again be brought

* *Proc. Roy. Soc.* (not yet published).

into phase and the sharp minimum obtained; so that if the constants of the circuit are known, the phase shift can be calculated from the amount of detuning required. Special difficulties of course arise when the phase difference is nearly 90°, but this does not occur often in practice.

CONSTRUCTIONAL DETAILS

(*a*) *Receiving Coils*. The set, of which a drawing is given in Fig. 2 and a detailed diagram of connections in Fig. 3, consists of two coils, each roughly 4 ft. 6 in. high and 5 ft. long, wound with 52 turns of bare copper wire in two layers, having an inductance of 8 mh.

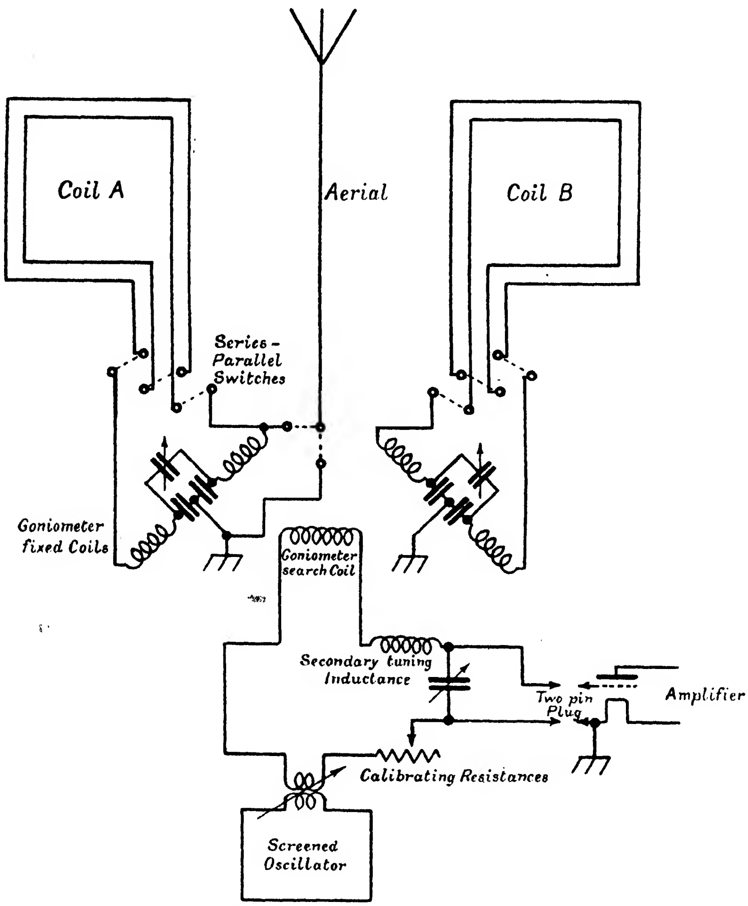


Fig. 3. Receiving Circuits—Diagram of Connections

This method of winding reduces considerably the depth of coil required, and also allows the sections to be used in series or parallel for different wave-lengths. Tapping cannot easily be used, owing to the difficulty of keeping the mutual induction between the two coils zero always. It certainly increases the effective H.F. resistance, but it will be seen later that in many cases this is no disadvantage.

The coils are mounted as shown on a vertical brass tube carrying a footstep bearing, their lowest points being 6 ft. from the ground; and at the top are carried in another bearing forming part of the containing hut, and fitted with a device to limit the angle of rotation to 400°. In series with one of the coils is a very small coil loosely coupled to the other main coil, which can be adjusted so as to make the mutual between the main coils exactly zero.

It was found impossible to do this sufficiently accurately during erection. Screened leads from these coils run down the brass tube to a screened terminal box just below it, where the necessary arrangements of connections can be made.

From the terminal box further screened leads run to the radiogoniometer, which is itself enclosed in an iron box 18 in. × 18 in. × 18 in., the front (brass) top plate of the goniometer being bolted to a large sheet of brass which forms the front panel and on which all the controls are mounted.

In order to obtain the symmetry with regard to earth necessary to give true and sharp minima on the goniometer, the coils are actually connected as shown in Fig. 3, this being possible owing to each fixed coil of the goniometer being made in two sections. The condensers A are selected pairs, their values being 0·01 or 0·02 μ fd. each, according to the wave-length in use; all intermediate tuning being done on condensers B. Hand capacity effects are eliminated owing to the front panel of the set being an earthed sheet of brass.

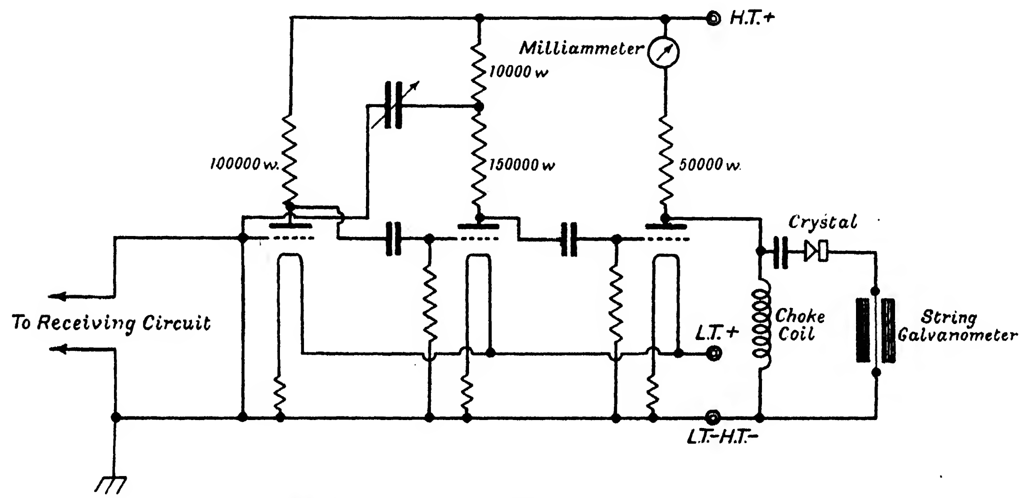


Fig. 4. Amplifier—Diagram of Connections

(*b*) *Secondary Circuit*. The secondary circuit includes the search coil of the goniometer, and two standard Igranic coils mounted in an iron box a few inches apart but in opposition, so that they are practically astatic to external fields. The necessary tuning condensers and resistance for calibrating purposes are also included. It has been found by experience that total screening of these coils is unnecessary, and the lid of the screening box is usually left off, so that change of coils for different wave-lengths can be carried out at once; but it can always be fitted if required.

(*c*) *Amplifier*. The standard type of resistance-capacity amplifier is used with certain modifications suggested by experience (Fig. 4). The chief of these are the use of P.M. 5 A. valves, which have a high amplification factor, and the arrangement of the connections of the reaction condenser, which is now placed across part of the anode resistance of the second valve instead of across the whole. In this way a larger reaction condenser can be used, the slow motion of which gives perfect control of the reaction. The balanced anode system previously used in the last value has been given up; its place being taken by a crystal connected as shown. Provided care is taken in the choice of a crystal, and it is shielded from electrical shocks by keeping its switch open except when observing, the whole arrangement works very satisfactorily and maintains its calibration for days together.

(*d*) *Calibrating Circuit*. The calibration E.M.F. is applied direct to the amplifier, by means of a Dye Transformer, as in the previous system. In this connection it is important to note

that no calibrating method would be practicable which relied on injection straight into a receiving coil set in zero field; since, when abnormal polarization is present, no zero field is obtainable. A "dummy" screened aerial of small size could not be used, as it would be impossible, without great labour and expense at any rate, to make an inductance of much smaller size possessing as low an H.F. resistance as the receiving coil. Since, however, the receiving coils are not connected direct to an amplifier, their H.F. resistance is not liable to variation, and they can be calibrated once for all and checked occasionally.

To save space the coils and condensers used for the secondary receiving circuit are also used as the oscillating circuit for feeding the Dye Transformer. This is possible since they are never required for both purposes simultaneously, and it ensures that the calibrating E.M.F. is supplied at the correct frequency without further adjustment. It has involved the abolition of the "receive-calibrate" switch system used on the tuning panel of the old set,

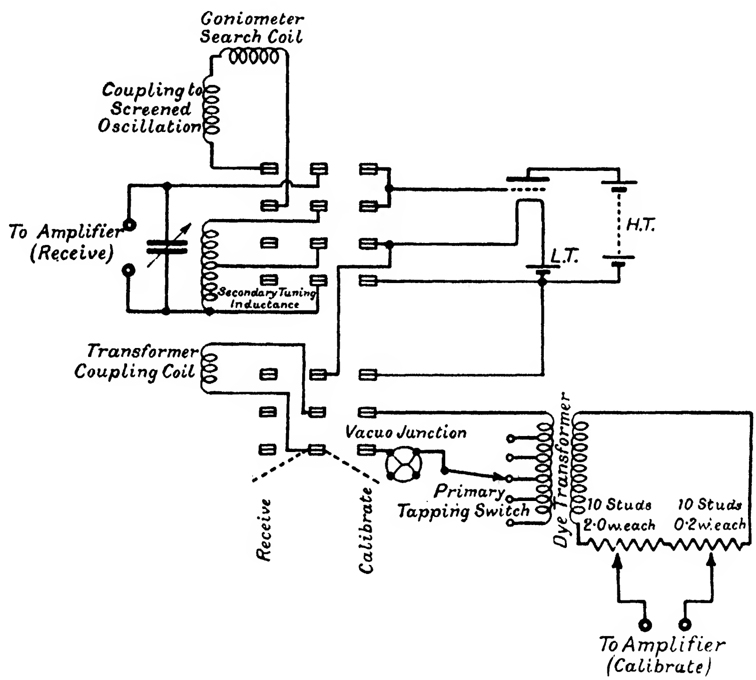


Fig. 5 Calibrating Circuits—Diagram of Connections

owing to leakage dangers, and the amplifier input now terminates in a two pin plug placed in either of the "receive" or "calibrate" sockets which are some distance apart. The change over from "receive" to "calibrate" involves some rather elaborate switching (Fig. 5); but provided the switches are of good quality, this appears to give no trouble. A screened oscillator of the standard type is also provided; the variable coupling coils being arranged on a slow-motion screw and connected so as to inject an E.M.F. into the secondary circuit. This has proved of great value for calibrating and testing purposes.

In order to enable measurements of the down-coming angle of nearby transmissions to be made, an aerial is incorporated in the set. On these long waves, unlike the shorter ones, it is not possible to wait for a time at which the surface and down-coming waves come into phase. To compensate for this it is necessary to measure the relative intensities in coil and aerial, and also the phase angle between them. Also on these long waves the loading of a small aerial up to the long wave-lengths is a serious problem, so in this set the aerial is connected to the end of one of the coils and the phase comparison made between coil and

(aerial + coil). The aerial consists of a straight vertical wire about 40 ft. long passing down through the centre of the coils, and terminating in a throw-over switch.

Calculation has shown that under these conditions the addition of the aerial has no appreciable effect on the coil constants, and its action is simply to add to the coil E.M.F. another E.M.F. 90° out of phase with it, and of an intensity $= \frac{E_g h C_1}{C_2}$ where E_g is the gradient, h the effect height, C_1 the capacity of the aerial and C_2 the tuning capacity across the coil subject to the condition $C_2 \gg C_1$.

h and C_1 are difficult quantities to measure separately, but as they always occur as a product, this can be determined by measuring the relative intensities on coil and (aerial + coil) of a station so far away that the effect of the down-coming angle (of which the cosine only is involved) is negligible. Actual experiment has shown that the product hC_2 remains constant over the wave-band at present in use.

Theory of Operation

(*a*) In this method, as in the original, all measurements depend on a knowledge of the circuit constants, and it is therefore necessary either to know these or to have means at hand for measuring them. Now if we have two coupled circuits of resistances R_1 and R_2 and mutual inductance M, it can be shown that if an E.M.F. E is induced in the primary, the resultant current in the secondary when in tune is

$$I_2 = \frac{EMp}{R_1 R_2 + M^2 p^2} \qquad \text{......(1).}$$

This is subject to certain limitations in the value of M, for if this is too great compared with R_1 and R_2 "double peak" tuning with its attendant complications arises. Calculation and experiment have shown that this does not occur in this case, M being only 36 microhenries. Moreover the special purpose of the set is to study abnormal polarization; and for this to be of measurable intensity the down-coming wave must make an appreciable angle with the horizontal. The majority of observations are thus confined to stations less than 1000 km. away, so that signals are always of considerable intensity, and very low circuit resistances are actually undesirable. In fact, to make the phase measurements simpler, resistance is often actually added to the receiving coil circuits.

Of the unknowns in equation (1), R_2 is the only one seriously subject to variation, since it is connected to the amplifier and therefore involves the reactive effect of the latter. For the measurement of this, known resistances are included in the secondary circuit, and it is measured in the same way as in the original set. All the other constants involved have no definite tendency to vary, and can thus be determined once and for all, and checked periodically if necessary. Although it is not safe to assume in general that M^2p^2 is negligible compared with R_1R_2 it frequently happens that this is the case, and a considerable simplification of the operations then results.

(*b*) *Phase Measurement.* It is important to note that the phase observation is a null method. Hence at the instant of observation there is no mutual reaction between the various circuits through the radiogoniometer, and consequently the constants of each circuit are the same as if it were working separately and independently.

Now if a simple circuit is in tune with a capacity K and is then detuned by a small amount dK, the resulting phase change θ is given by

$$\tan\theta = \frac{dK}{K} \times \frac{1}{KpR_1} \qquad \text{......(2).}$$

The resistance R_1 of the primary circuit being known, and also the calibration of the small

variable condenser, the value of θ can be calculated at once for a given amount of detuning on any particular station.

It will be seen from this that the larger R can be made the more accurate is the phasing; subject however to the increasing difficulty of determining the exact point at which the circuit is actually in tune, which can however be largely overcome by the following special method of operation. Since θ is derived from tan θ and is thus a straight line for small values of θ the resultant error is very small provided the mistuning of each circuit is the same. Hence the condensers can be set by injecting a signal of the same wave-length into both coils by induction from a local source; tuning one coil as accurately as possible and then adjusting the tuning of the other until a sharp minimum is obtained on the goniometer.

Method of Operation

For a normal intensity measurement, the apparatus is operated in a manner closely similar to the original set. One coil is set in the required direction and the signal tuned as usual. Now if it is known from previous experience that the signal intensity and amplifier setting are such that $R_1R_2 \gg M^2p^2$, it is sufficient for the determination of R_2 to insert resistances in the secondary circuit in the usual way; for in this case equation (1) becomes

$$I_2 = \frac{EMp}{R_1R_2}.$$

If however the intensity is low, and consequently the secondary circuit highly reactive and its apparent resistance low, this method is not sufficiently accurate.

The same procedure can be adopted, and allowance made for the known value of M^2p^2 in equation (1); but a more convenient method is to short-circuit the primary coil, and then inject from the screened oscillator a steady E.M.F. of the same wave-length and roughly the same intensity as the signal to be measured. Resistances are then inserted in the usual way, all points calibrated and the signal E.M.F. calculated. Actually it has been found that, on the shorter waves where M^2p^2 is increasing rapidly, the observations become more difficult and less reliable; and it is the value of this mutual rather than the characteristics of any other part of the apparatus which sets a lower limit to the wave-length range.

In the case of a sunset run, or any observation in which polarization measurements are required, the procedure is slightly more elaborate. Both coils are used, being set at 45° on either side of the direction of the station under observation. Each is carefully tuned separately, and the reading on the variable primary condensers noted. The goniometer is then set so as to receive the E.M.F. from one coil only, and the reading on the string galvanometer noted; and the same process is carried out on the other coil by turning the goniometer through 90°.

For the phase measurement the goniometer is turned to an intermediate position, when, if the two E.M.F.'s are in phase, a complete extinction of the signal will be found. If the extinction is not complete, one of the primary condensers is moved until it is, and the amount of change necessary to produce this is noted. The intensity calibration can be carried out in the usual way, but for a run of several hours the following procedure has been found more convenient.

Experience has shown that with all batteries, etc., in good condition the set will retain its calibration for several days. The screened oscillator is therefore set to inject a signal into the secondary circuit (both primaries being short-circuited), giving a deflection on the string galvanometer about equal to that of the signal under observation. This is calibrated before and after the run, but left untouched during the intermediate period, and occasionally switched on as a check. From this a calibration curve between signal intensity and string galvanometer deflection can be drawn, and intensities read off directly from the curve,

which is of the greatest value in cases where the intensity is changing very rapidly. It is probable that, owing to the slight uncertainty as to the high-frequency value of M and the fact that the resistances of two circuits are involved, the total accuracy is no greater than that of the original set. But owing to the constancy of the apparatus the relative values are much more true, and it is on these that the accuracy of the solution frequently depends rather than on the absolute values.

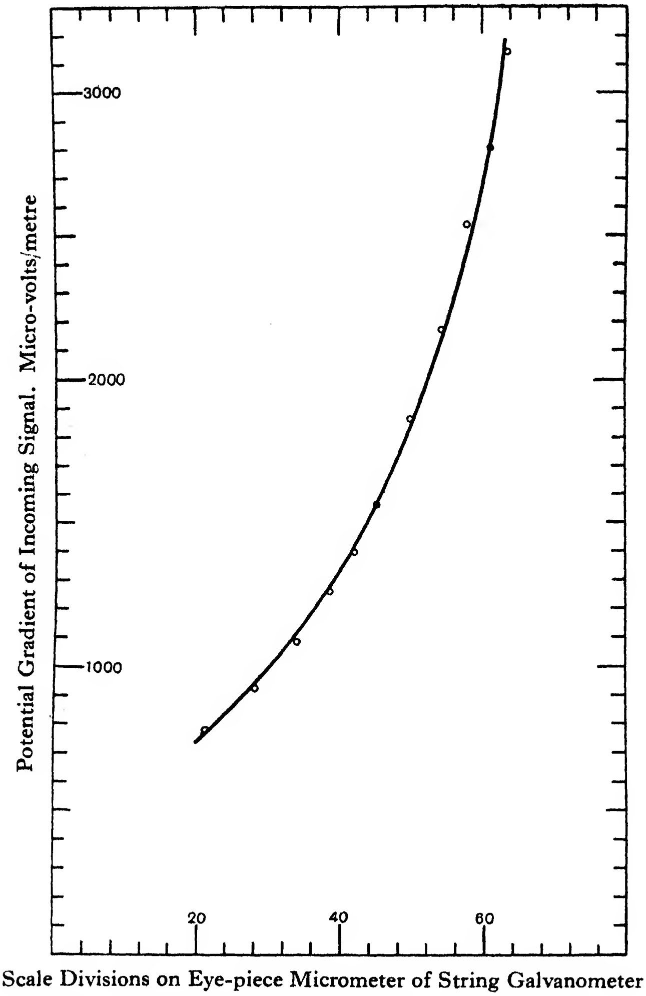


Fig. 6. Calibration Curve for Wave-Length 14,350 m.

The equations which determine the unknowns from the observations are vectorial, and can best be solved graphically. Cases of course occur in which the accuracy here is low due to the degenerate shape of the vector triangles; but this is a difficulty for which the set is in no way responsible.

As an illustration of the working of the apparatus, Fig 6 gives the calibration curve of intensity actually in use at present. This by no means represents the limit of sensitivity of the apparatus, as the station now under observation is a powerful one. Owing to the design of the apparatus and the fine control of reaction it is always possible, within limits of course, to obtain a full scale deflection for any required signal intensity, and so obtain the same percentage accuracy of observation throughout. At present, while measurements are

being taken of certain definite cycles of observation, it is set so as to cover the expected range without adjustment; for if this has to be done during a period of rapid variation it may result in a loss of valuable information.

Summary

The apparatus described above appears to be the most comprehensive yet devised for the analysis of long-wave propagation. In addition to the tests described in detail above, certain other observations can be made for special purposes. Working experience has suggested many minor modifications in construction and operation which are not of sufficient importance to be described here, but which have added considerably to the accuracy and ease of operation. It is most important that the set should be as instrumentally and mechanically perfect as possible, and it is necessary to give quite as much consideration in the design to mechanical reliability as to wireless accuracy, for in work of this nature observations can often never be repeated, so that it is necessary to be absolutely certain that the variations which occur are not instrumental.

When used as described above, it becomes practically a direct-reading instrument, and, if used with proper care, the accuracy appears often to be dependent rather on the constancy and steadiness of the transmission than on the instrumental reliability.

This work was carried out for the Radio Research Board under the Department of Scientific and Industrial Research, and I am indebted to the Committee on Propagation of Waves for their helpful criticism.

I must also express my thanks to my colleague Mr Naismith for his assistance in the construction and calibration, and to Mr Willmotte of the National Physical Laboratory, to whose suggestion the idea of the phase measurement was originally due.

QUARTZ-METAL JOINTS, AND THEIR APPLICATION TO STANDARD AIR CONDENSERS OF LOW RANGE.

By D. A. OLIVER. Electrical Department, National Physical Laboratory.

[*MS. received*, 15*th August*, 1927.]

ABSTRACT. A relatively easy method of making quartz-metal joints is described. In the case of quartz rods or tubes, the ends are platinised, plated and tinned, as in Snow's glass-metal joint procedure. They are then inserted into special tinned sockets of simple form and the joint made with Wood's metal. The application of such joints to the construction of high class air condensers of low minimum capacity is pointed out, and the design for a standard of approximately 50 micro-microfarads range is given in detail.

Introduction

The use of pure fused quartz in the form of rods, tubes and washers has been considerably extended during the last few years as the demands for good insulation in electrical apparatus have become more stringent. Short rods are now used to insulate the quadrants of electrometers and have been employed for some years at most of the national laboratories in the construction of standard air condensers. One of the obstacles encountered in its utilization is the difficulty of mounting. Owing to its extreme hardness it is impracticable to grind screw threads upon it, and the problem resolves itself, in the case of rods and tubes, into the application, for the purpose in view, of pieces with ends ground plane and parallel. A comparatively simple and successful method has been used by the writer for the fixing of such pieces of quartz into metal caps and seatings, and this will be described first.

Quartz-metal Joints

The general procedure has already been published by Snow* in connection with the fixing of silver thimbles on to glass tubes, but will be given here for completeness together with the additional special points to be observed. The quartz which, from an electrical point of view, is preferably of the fused variety, should first have the surfaces at which the joints are to be made slightly matted by grinding. The specimen is thoroughly cleaned in a solution of potassium permanganate, strong sulphuric acid being added, which removes any trace of grease or finger marks from the surface. Washing in distilled water and strongly heating in a blow-pipe flame for about 5 min. follow, care being taken not to finger any part after the cleaning process. While still warm, the matt ends are painted thinly with a platinising solution† and are heated slowly at first and afterwards more strongly in a bunsen flame until a bright mirror of platinum makes its appearance. A second coating is usually desirable, after which the platinised ends are copper plated until a perceptible coating of copper covers the initial film, the coppered ends being then nickel plated, which affords the final protection. A small cage, forming the cathode, was made of copper wire into which the rod was stood and rotated at intervals to ensure all portions getting a uniform coating. Traces of plating

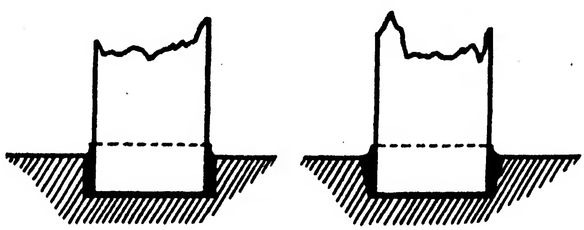


Fig. 1. Forms of seating for quartz rods and tubes

salts are removed by thorough washing in distilled water and the specimen is then dried in an oven. The nickelled ends and metal seatings are tinned with ordinary solder, using fluxite, by careful heating in a bunsen flame.

In the early experiments, the simple form of seating shown in Fig. 1 *a*, was adopted and the joint made with ordinary solder. Owing to the fact that silica has no appreciable thermal expansion compared with, say, brass, and that ordinary solder solidifies at a fairly high temperature, fracture due to compression occurred on cooling. A similar joint was made, with a bevelled edge to the seating as shown in Fig. 1 *b*, using solder as before. Even this did not quite overcome the cracking produced by the lack of flow of the solder in the last stages of cooling, but Wood's metal, with rosin as a flux, associated with a seating of the form given in Fig. 1 *b*, proved perfectly satisfactory. The usual tinned surfaces enable the low melting-point alloy to flow readily, which it would not do otherwise, and a mechanically sound joint ensues. The quartz is now gripped under slight compression which is not altogether an undesirable feature. Lastly, a fine blow-pipe flame is made to impinge on the middle of the rod or tube after the joints have been made to remove any moisture still adhering to the surface, which would seriously lower the surface leakage resistance.

These joints possess the important advantage of being suitable for vacuum work at normal temperatures. No experiments have been carried out on joints suitable for high temperatures, but it seems probable that if invar seatings were employed, no difficulty

* *Journ. Scient. Instr.* **1** (1924) 126.

† *E.g.* "Liquid Platinum," Messrs Johnson, Matthey and Co., London.

would be experienced in making the joint with high melting-point solder, or, should this prove unsatisfactory, with high melting-point solder to which antimony* has been added in such a proportion as to prevent contraction on cooling.

Variable Standards of Capacity

It was shown by the author† recently that, in designing small variable air condensers, the lowest minimum capacities were obtained when the moving system was insulated on the underside of the top bearing. Subsequently, among others, the design of a standard of about 50 micromicrofarads range was undertaken, the object being to secure the lowest minimum capacity compatible with first class mechanical construction and permanence, as the instruments were required as sub-standards of a high order. On this account, the radius of the moving plates was kept fairly low and the air gap between the plate systems made equal to 2 mm. so that any secular change due to slight plate sag might be very small or quite negligible. The air gap is an important factor in the design, the minimum capacity being greater the larger the air gap for a specified total change of capacity.

If the capacity of a condenser is doubled by adding more plates it is common experience that the minimum value is not increased to the same extent. This is obviously due to the presence of a comparatively large capacity, which is not dependent upon the size and number of plates, and which naturally, in good designs, is made as small as possible. The capacity of the terminal and the connection between it and the insulated system forms a considerable percentage of this quantity, being often about one-third of the actual minimum value. In those instruments of 4–24 micromicrofarads range the lead-out was simply passed through a fairly large hole in the side of the case, but here the terminal of the lead-out is mounted on a quartz washer, thus making the inside dust-proof and approximately air-tight. By complete enclosure, means can be adopted to dry the air inside by calcium chloride tubes should the dielectric losses associated with air of normal humidity prove of any consequence.

The drawings for the condenser of approximately 50 $\mu\mu$F range are given in Fig. 2, with the section of the insulated terminal included in the elevation. Many features in the mechanical design have been derived from other standards which have been developed from time to time in the Electrical Measurements Department, National Physical Laboratory. The moving plate system is insulated by means of a rod of clear fused quartz, which forms part of the spindle. The ends of the rod are let into the brasswork and secured by joints of the kind already given in detail. A simple jig for holding the metal stems and seatings during the final operation of making the joint is shown in Fig. 3. This device, due to Mr A. Gridley of the Instrument Shop of the National Physical Laboratory, enables perfect co-linearity of the two stem axes to be attained with ease. The two "V" grooves were cut at one set up on the planing machine, after the two end blocks had been sweated on to the bar which forms the base. Two pieces of brass rod, one tapped out to take the screwed portion of the upper seating and the other drilled out to be a push fit over the stem of the lower one, enabled the most simple clamping arrangements to be adopted. When this jig is employed, it is quite immaterial if the plane ends of the quartz rod are not parallel.

A bronze bearing locates the moving plates, and the weight of the system together with the spring washer provided on the underside of the bearing serve to maintain the rubbing surfaces in contact with a fair pressure between them. Tallow, freed from acid, is often employed as a lubricant, but unfortunately it is apt to harden and produce a stickiness in the bearing which makes minute smooth adjustments of capacity impossible. Pure mineral oil, vaseline, and paraffin wax, heated and mixed together, give a moderately stiff acid-free

* Kaye, *High Vacua*, p. 68, Longmans, 1927.

† *Journ. Scient. Instr.* 4 (1926) No. 3.

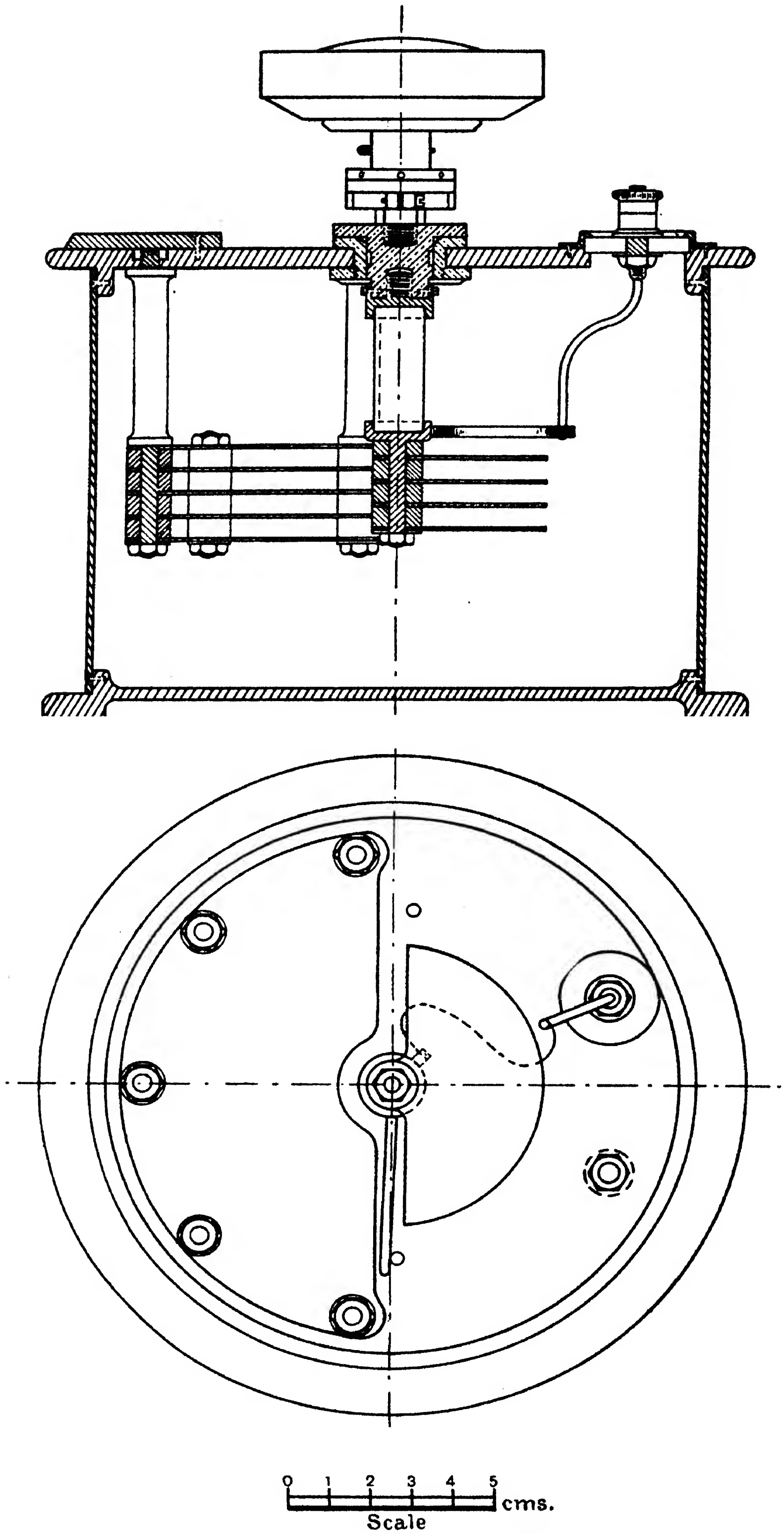


Fig. 2. 50 $\mu\mu$F Standard Variable Air Condenser with quartz rod insulation

lubricant which for months has given every satisfaction, the actual proportions used being about 1 : 4 : 10 by volume. Generally speaking, the lubrication of condenser bearings deserves careful attention as re-calibration is necessary every time the instruments have to be dismantled on this account.

A thin flexible strip of phosphor bronze connects the moving plates to the stiff copper wire of the insulated terminal, and consequently the movement must be limited by stops. American practice favours a rubbing contact with a perfectly free moving system, but resistance uncertainties at such contacts are apt to be more serious than the occasional slight mechanical shocks induced when stops are present. The use of the pointer as a means of limiting the extent of the variation is much to be deprecated. Under such conditions the pointer is bound to work loose in time with the reversed impacts against the stops, especially in the case of those pointers provided with means of adjustment. In common with all the standard variable condensers of the Department, the condenser of Fig. 2 has a separate brass rod, working against two stops. This rod is screwed directly into the main portion of the bearing through part of the upper seating, which is thus further prevented from unscrewing. The spindle carrying the pointer and knob is screwed and soldered into position.

The seating for the quartz washer should be well made and the washer itself bedded down

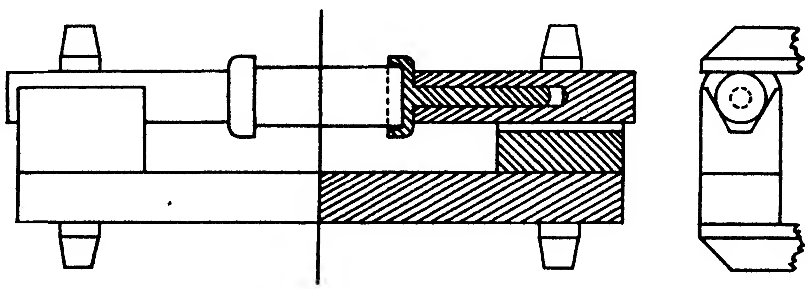


Fig. 3. Jig for holding quartz rod and seatings while making the joint

on tinfoil, otherwise fracture may occur either at the time or subsequently. The washer is, of course, cleaned in the same way as the rod and heated in a blow-pipe flame to make it good electrically.

With regard to the fixed plates connected to the brass case forming the screen, five equi-spaced rods with separating washers were considered satisfactory, although no electrical disadvantages would attend the use of semicircular separating rings such as are employed in some of the best designs of high range standards*. Three of the rods are extended to support the bank of plates from above and are secured by recessed nuts under the polished aluminium scale.

Measurements were made of the component capacities at the minimum setting and are given in the following table.

Table

Condenser of 50 $\mu\mu$F *Range*, Fig. 2.
Component Capacities at the Minimum Setting

	$\mu\mu$F
Insulated terminal and lead-out	3·3
Lower seating, separating washers and nut	1·7
Top moving plate	1·5
Middle two moving plates, each 0·5 $\mu\mu$F	1·0
Bottom moving plate	1·6
	9·1

* *E.g. N.P.L. Annual Report* (1924) p. 84.

The values refer to the assembled instrument, and thus it will be noticed that the intermediate plates in a bank are largely shielded by the end ones. A practically constant capacity of 5 $\mu\mu$F is seen to be present in this instance. Measurements of the type given above enable fairly accurate predictions of minima to be made for similar standards of different range. The maximum capacity was actually 67·5 $\mu\mu$F, giving a ratio of maximum to minimum of 7 : 1. In a similar standard six moving plates were used, their radius being increased to leave 3 mm. clearance between the edges of the moving, and the separating washers of the five fixed, plates. The maximum and minimum capacities were 190 $\mu\mu$F and 17 $\mu\mu$F respectively, having a ratio of 11 : 1. The insulation, however, was not quite of the same design, and with the rod construction described here it is estimated that the lower value could be reduced by a further 2 $\mu\mu$F, which would give a final ratio of over 12 : 1.

Strict uniformity of the scale is only found within a limited central belt, as the scale opens out towards its extremities. Thus it is essential to calibrate such condensers throughout their range and for this purpose a standard of ten times the value can be employed in conjunction with a Schering Bridge having 1 : 10 ratio arms. The scales should be easily removable for engraving after the main graduations and small divisions near the extremes have been marked in experimentally.

The electrostatic shielding is perfect, if the presence of the insulated terminal is excluded. The error due to the unscreened terminal is less than $\frac{1}{20}$ $\mu\mu$F which is the limit of observation, as 3·5 mm. on the scale at a radius of 8 cm. represent 1 $\mu\mu$F.

Brass was used throughout for the construction, with the exception of those details already mentioned.

A SIMPLE METHOD OF MEASURING LOW PRESSURES.

By R. J. CLARK, Lecturer in Physics and Carnegie Teaching Fellow in the University of Edinburgh.

[*MS. received, 10th August*, 1927.]

ABSTRACT. A method of estimating very low pressures, which does not require anything but a McLeod gauge, and is sufficiently accurate for rough work, is to pump the gases from the exhausted vessel into a McLeod gauge, and measure the rate of increase of pressure therein.

It is often desirable to have some idea of the magnitude of the gas pressure inside an apparatus, and at the same time to avoid the use of Knudsen and ionization gauges. This is so when the absolute value of the pressure does not enter into the quantities measured during the course of the experiment. For instance, in experiments on molecular streams it is often necessary to know only that the pressure is less than some definite amount. This information can be got by a McLeod gauge alone, even though the pressure is much below the limit of the instrument as ordinarily used.

With the usual arrangement for using a diffusion pump, the pressure gauge is attached to the vessel in which the pressure has to be measured, and this pressure is measured directly. If a McLeod gauge is connected, not directly to the apparatus, but to the pumping system between the diffusion pump and its fore-pump, then by the use of a suitable system of taps, we can pump the gas from the evacuated vessel into the gauge. If the duration of this pumping is not too long, the back pressure set up will not interfere with the speed S of the pump, and we can write for the volume of gas delivered by the pump in t seconds,

$$V = St.$$

If P be the pressure in the apparatus then

$$PV = PSt.$$

If G be the total volume of the gauge and the tubing which connects it to the pump, and p the pressure indicated by it at the end of t seconds, then

$$pG = \text{const.} = PSt$$

or

$$P = \frac{pG}{St}.$$

The speed S is the corrected speed. Let S_1 be the speed of the pump when connected directly to the vessel being exhausted. Let S be the apparent speed and R the resistance of the tubing. Then

$$\frac{1}{S} = \frac{1}{S_1} + \frac{1}{R},$$

and to a sufficient approximation

$$\frac{1}{R} = 1{\cdot}6 \times 10^{-5} \left[M \, . \frac{273}{T}\right]^{\frac{1}{2}} . \frac{l}{D^3},$$

where l is the length of the tube, D its diameter, T the absolute temperature, and M the molecular weight of the gas.

Where a stream of gas is flowing continuously into an apparatus and being exhausted by the pump, the pressures indicated in this way are of the same order as those indicated by a Knudsen gauge on the apparatus itself.

This is a very convenient method of testing the pressure to find small leaks, as it greatly reduces the time of waiting required between readings of the pressure. In baking out an apparatus, it is useful for following the state of the process, for although it does not measure the pressure due to water-vapour, yet it gives indications of the amount of permanent gas coming off. To take an actual example, the corrected speed of the pump was 350 cm.^{3} per sec., and the volume of the gauge was 90 c.c. The fore vacuum was maintained by a Gaede rotary mercury pump which would pump to 10^{-4} mm. On raising the temperature of the oven to 400° C. the pressure at the delivery end of the diffusion pump was nearly 0·01 mm. Later on, as this pressure fell, it was possible to pump into the gauge, and this was done from time to time. At the end of three hours, pumping into the gauge for 3 minutes produced an increase of pressure therein of $2{\cdot}3 \times 10^{-4}$ mm. As there was a mercury trap cooled in liquid air on the exhaust line, water vapour is not shown, and this reading corresponds to a pressure of permanent gas only. This pressure is

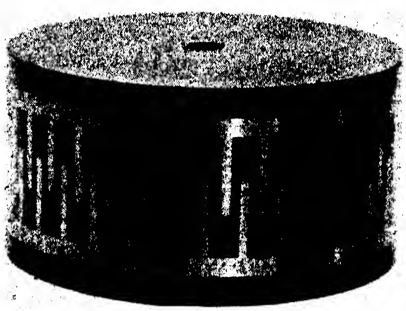
$$P = \frac{2{\cdot}3 \times 10^{-4} \times 90}{350 \times 3 \times 60} = 3{\cdot}3 \times 10^{-7} \text{ mm.}$$

The oven was then allowed to cool when the pressure fell to 1×10^{-7} mm. when measured in this way.

A curious thing is, that very little gas seems to come from the walls of the diffusion pump, at any rate after it has been working for half an hour. Presumably the layer of gas occluded on its walls is removed very rapidly by the stream of mercury vapour, and the temperature is not high enough to allow the gas to diffuse from the layers near to, but below the surface of the glass. This is true only when both the walls of the pump, and the surface of the mercury in it, are free from any visible deposit. Metal diffusion pumps have not been tried.

A NEW PROCESS FOR PRODUCING ELECTRICAL CONTACTS

The Precious Metal Industries, Ltd., have recently introduced a process devised by Mr A. I. Warren of Derby for the production of metal contacts, etc., embedded in ebonite or other insulated material, which seems to be of great interest. Mr Warren appears to have found that if metal foil, preferably of gold-silver alloy, is pressed into contact with ebonite or other substance containing rubber with a minimum of $7\frac{1}{2}$ per cent. of sulphur, and heated, a film of metallic sulphide is produced which gives very powerful adhesion, and, when the foil is stripped away, can be reduced by an ammoniacal solution so as to leave a thin, strongly adherent metal film upon which copper or other metal can be deposited electrically to form a strongly adherent layer.



He has more recently found that the foil can be replaced by coating the ebonite or other substance, where required, with a paste containing oxide of silver, which is heated in a hot air chamber and vulcanized, producing the metallic sulphide film which is reduced and deposited on as before. The process enables metallic layers of any shape to be deposited on the insulator, presumably in moulded or machined recesses, and at our suggestion the firm has kindly produced a commutator of the well-known Fleming form for condenser measurements, a photograph of which is shown. The metal appears to be perfectly uniform, with an excellent polished surface, and the advantage of being able to build up such a commutator without joints needs no enlarging upon. It is understood that the thickness of the metal is usually from 10 to 20 thousandths of an inch, but that there would be no difficulty in making it thicker.

There would seem to be a very great utility for this process for many electrical instruments, and we are glad to be able to call the attention of instrument manufacturers to it.

The address of the company is Bridge House, 181 Queen Victoria Street, London, E.C. 4.

NEW INSTRUMENTS

AUTOMATIC COMBUSTION CONTROL

MODERN boiler practice has tended more and more to replace human labour and judgment in stoking and regulating fuel and air supply to the furnaces by mechanical stokers and instruments for indicating and recording the furnace and flue temperatures, percentage of carbonic acid in the flue gases, etc., to which the attendant can refer to guide his regulation of the feed and dampers. The Leeds and Northrup Company of Philadelphia have, however, taken the bold step of employing the instruments to control the stokers, dampers, and fans so as to obtain completely automatic operation of the furnaces, and have issued a Bulletin, No. 660, describing the system.

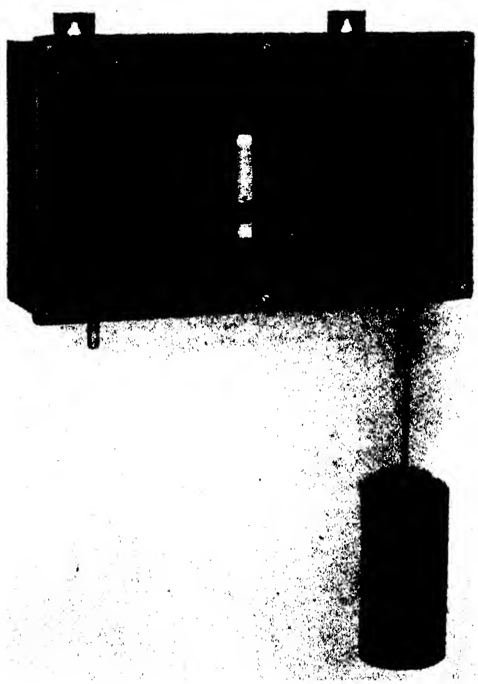


Fig. 1

The chief features from the instrumental point of view are the controllers, of which there are four, one actuated by the steam pressure, and the other three controlling the fuel feed, the air flow and the furnace pressure respectively. The first or master controller is shown in Fig. 1, and consists of a pressure gauge with spring and weight control and a contact arm with variable lever ratio moving over the contacts of a rheostat. The normal pressure can be balanced by changing the weight, and the full range of control can be obtained for pressure changes from 5 to 20 lb. by varying the lever ratio.

All the other three controllers are similar, and consist of differential pressure balances, as illustrated diagrammatically in Fig. 2 and externally in Fig. 3. The higher of the two pressures is introduced into a bell, which is attached to one end of a balance arm and is

sealed by a layer of oil at the bottom of the case, the interior of which is at the lower pressure. Fixed to the balance arm, above the pivot, is a solenoid moving between two similar fixed solenoids, and a current is passed through all these three coils in series, causing the central moving coil to be attracted to the right hand and repelled from the left hand fixed coil, and therefore to oppose the lifting of the bell with a force proportional to the square of the current. A contact on the arm carrying the moving coil moves between two fixed

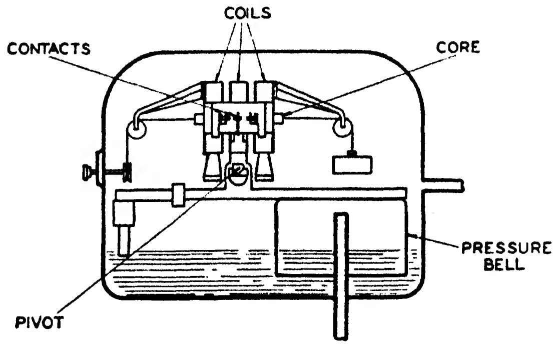


Fig. 2. Diagrammatic cross section of air flow balance

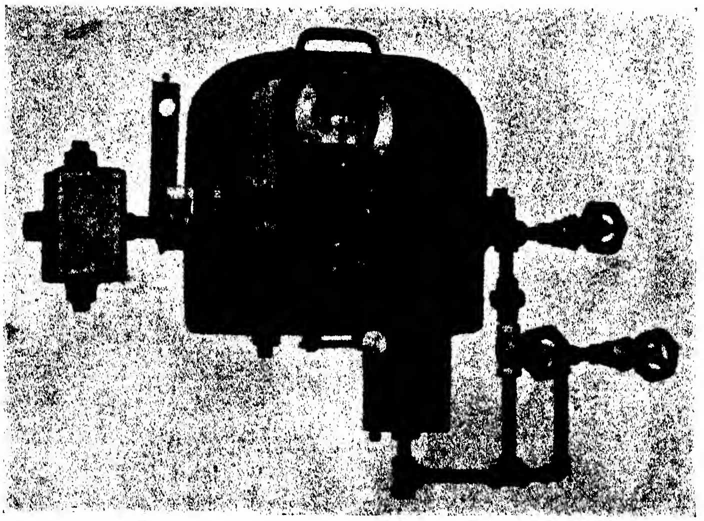


Fig. 3

contacts, and when it touches either of them it actuates a motor device which increases or diminishes the current until balance is restored. A moveable iron core extends through all three solenoids and can be adjusted so as to vary the current required for balance over a range of about 30 per cent., to suit individual conditions.

For controlling the air flow all that is necessary is to connect the pipes leading to the bell and case of the controller to two points on the air supply main. As the fall of pressure is proportional to the square of the velocity of flow, and the restoring force of the balancing current is proportional to the square of that current, there is a linear relation between balancing current and air flow, and the latter can therefore be read on an ammeter. The application to furnace pressure is obvious, while for fuel feed control all that is necessary is to drive a small fan from the stoker mechanism, as the pressure developed by it is then

proportional to the square of the rate of feed, which can therefore be indicated on another ammeter.

Fig. 4 shows the motor drive unit which works in conjunction with the contacts of the above controllers. It consists of a reversible motor, presumably of the usual double field series type, and is provided with a magnetic brake, when necessary to prevent over-running, and a high reduction gear box, the low speed shaft of which may be either horizontal or

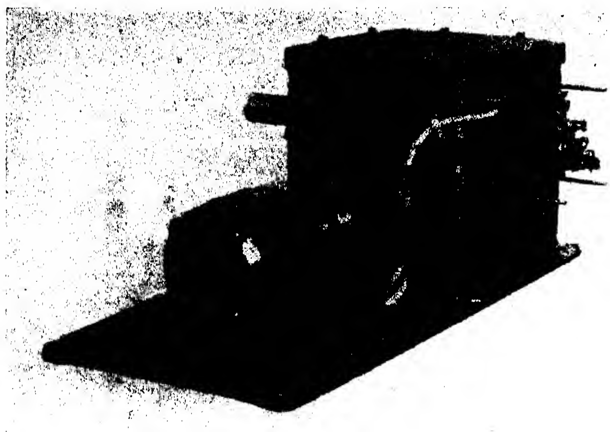


Fig 4

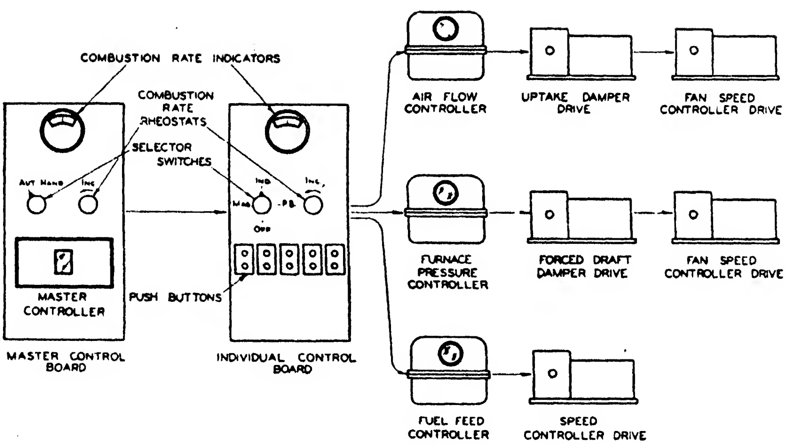


Fig. 5 Schematic arrangement of Leeds and Northrup control units

vertical and which is employed to move the regulator of the fuel feed or fan motors and the dampers. Fig. 5 is a schematic diagram of the whole system. Push button control is provided for the various motors, and in the event of any part of the gear failing an alarm is sounded and hand control guided by the indicators can be substituted.

The pamphlet concludes with some diagrams from recorders, showing the constancy of steam pressure and percentage of carbon dioxide in the flue gases secured by the control system applied to a powder fuel fired plant having great fluctuations of load, which show constancy of steam pressure to about ± 1 per cent.; and a percentage of CO_2 which was maintained within extreme limits of 14·4 and 15·5 over a twelve-hour run.

THE MIDWORTH DISTANT REPEATER

In our description of the last exhibition of the Physical and Optical Societies we drew attention to the ingenious method of transmitting indications devised by Mr Midworth of Messrs Evershed and Vignoles. The firm has now issued a descriptive pamphlet on the device, to which we are indebted for the following particulars.

The essential feature of the method is a series circuit containing the controller and any number of repeaters which are simply milliammeters of similar calibration, and this circuit is supplied from a potentiometer rheostat fed from a battery or supply mains, the exact steadiness of which is not of importance. The controller contains a milliammeter movement of similar range, so that whatever may be the current in the circuit the indication of the controller and of all the repeaters is the same. Coaxial with the axis of the controller

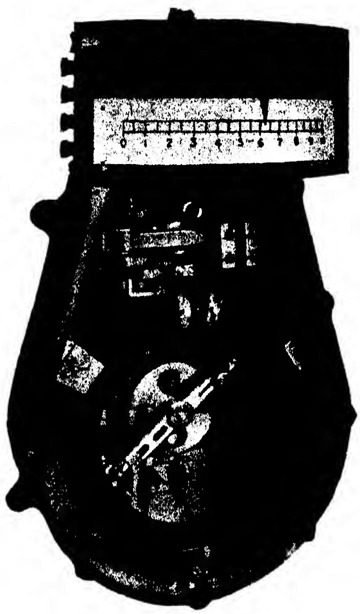


Fig. 1. Transmitter with cover removed

instrument is an arm or "control pointer" which can be mechanically rotated by a worm wheel and worm, and this arm carries two contacts on opposite sides of the instrument pointer. The two contacts are connected to the double field winding of a motor, so that this motor runs in one or other direction when either contact is made, and is stopped suddenly by the brake when the pointer is between the contacts; and this motor causes a rotating contact arm to traverse the circular potentiometer rheostat and thus raise or lower the current in the series circuit.

To transmit any desired indication therefore, it is only necessary to set the index on the control pointer to the required indication on the transmitter scale, by turning the worm spindle and the contacts, thereby causing the motor to turn until the current reaches the value for which the pointer is between the contacts, and all the repeaters will then indicate the same reading. Variation of the supply voltage is automatically compensated, as if it rises or falls the controller milliammeter makes contact on one or other side and resets the potentiometer arm to restore the current to the same value. Similarly, variations in the

line resistance or number of repeater instruments, within certain limits, has no effect on the transmission.

Should a break in the transmission circuit occur the potentiometer arm will obviously travel round in the direction which would normally cause an increase of current, and will

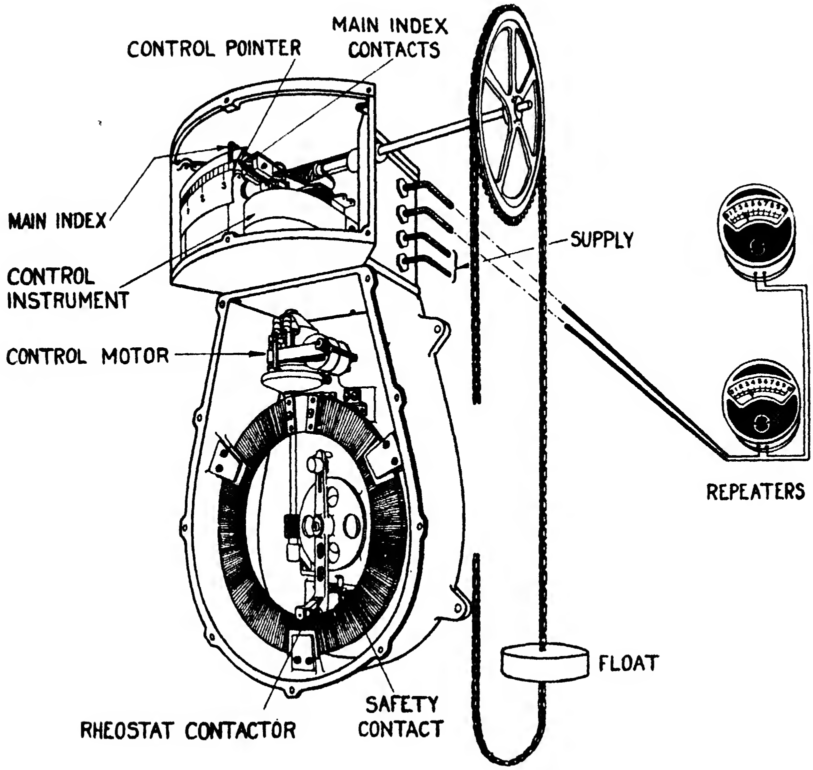


Fig. 2. Diagram of transmitter and repeating instruments arranged for indicating water level at a distance

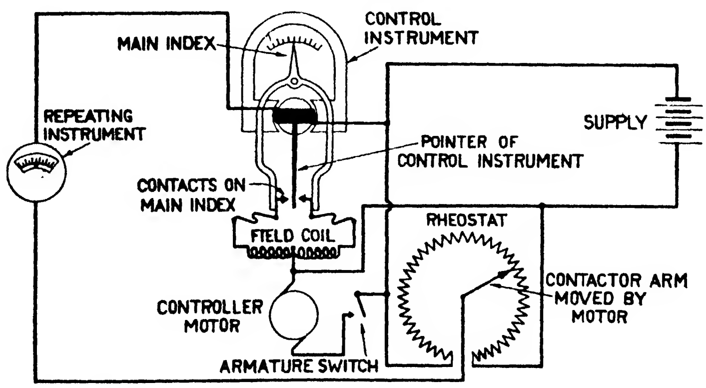


Fig. 3. Explanatory diagram of connections

continue to do so until it reaches a safety contact, which breaks one of the field coils of the motor and prevents it from running any further in that direction. As the other winding is left operative, however, a restoration of the transmission circuit will cause the potentiometer contact to travel back to the balance position and the system will continue to function normally. Figs. 1, 2 and 3 show the transmitter and its connections and will be readily understood from the foregoing explanation.

The uses of the device are very numerous. The position of any mechanism can be indicated at any number of points by gearing it to the worm of the transmitter, and any other mechanism, such as the rudder of a ship, may be made to follow it by gearing to a similar transmitter and employing a motor actuated from the contacts of this transmitter. The indications of any type of instrument can be transmitted and recorded or integrated

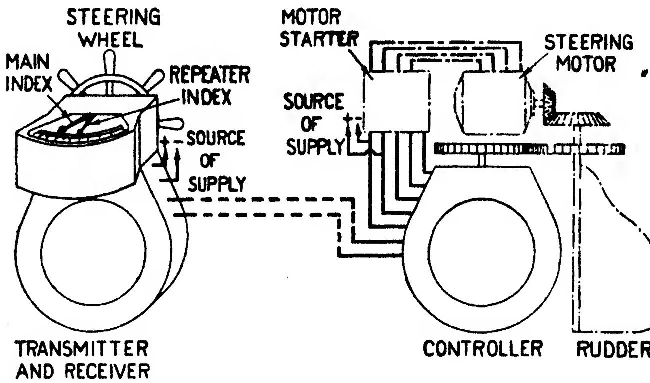


Fig. 4. Diagram of arrangement for distant control of mechanism

by employing a recorder or quantity meter at the receiving end. When a delicate instrument such as a galvanometer is used as an originating movement, its free movement is in no way hampered by the transmitting mechanism owing to the fact that, except during transition periods, there is no connection whatever between the originating movement and the transmitting mechanism.

Finally, two transmitters can be used together as a selecting device, whereby any number of separate instruments, as many as 40, for example, can be made to actuate corresponding indicators, with only four wires between the two transmitters. Fig. 4 shows the arrangement of the device for controlling steering gear.

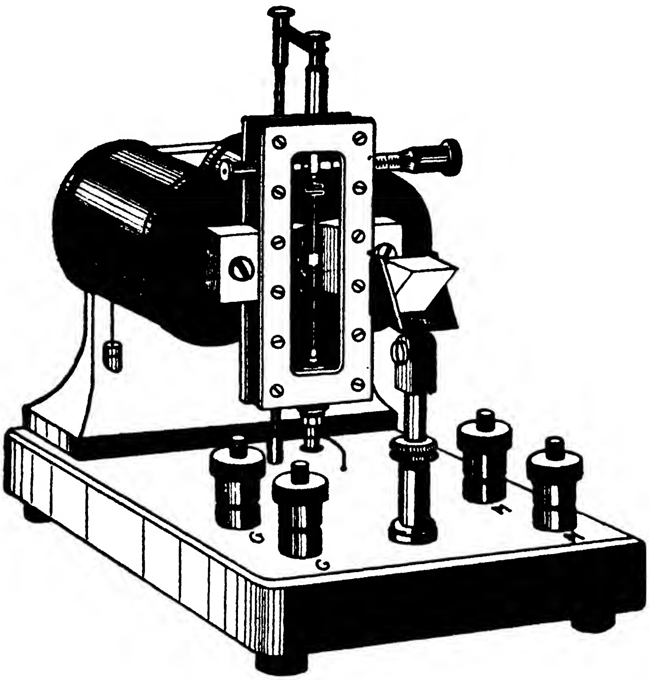
THE MOLL VIBRATION GALVANOMETER

In the issue of this *Journal* for August 1925 Dr Moll of Utrecht described a new and simple form of vibration galvanometer, consisting of an electromagnet with transverse fibre, as in the ordinary string galvanometer, but having a small unbalanced mirror at the centre of the string, so that the transverse vibrations of the latter, when alternating current is passed through it, cause the mirror to oscillate round the fibre. By varying the tension on the fibre the natural period of this oscillation can be varied over very wide limits—apparently from 100 to 2500 ~ per sec.—without change of fibre. The strength of the field, which has no influence on the tuning, can be varied to give the maximum sensitiveness under different conditions, a strong field being desirable for circuits of high resistance, but a weak one for low resistance circuits where a strong field would produce great electromagnetic damping of the fibre.

The annexed illustration shows the form of the instrument as now made by Messrs P. J. Kipp & Zonen of Delft, in which the horizontal electromagnet, having a resistance of 5Ω for a maximum current of 1 amp., is provided with narrow pole tips between which the 30Ω tungsten fibre with its small unbalanced mirror moves. The two ends of the fibre are attached to crimped springs, the upper one of which can be raised and lowered by the screw on the right so as to vary the tension. It is enclosed in an airtight framework

with a plate glass window, and a right-angled prism is provided so that the illumination can be furnished by a projector fixed vertically over the instrument.

According to a pamphlet issued by the makers the sensitivity of the instrument depends on the frequency and the magnetic field; the maximum sensitivity being 30 mm. at 1 metre per microampere at 260 ~. At 1000 ~ the deflection is 3·5 mm., and at 2500 ~ 2 mm. per



microampere. Tuning should be effected by turning the tuning screw when no current is passed through the magnet, as the resonance is sharpest with the weak residual field. When exactly tuned, the magnetizing current can be regulated to give the maximum deflection.

The instrument fulfils the requirement laid down by the editor in his Physical Society lecture that the inertia of the moving element in a vibration galvanometer should be concentrated into a single rigid mass, in order to avoid response to higher harmonics.

LABORATORY AND WORKSHOP NOTES

NOTE ON THE PREPARATION OF OXYGEN-FREE NITROGEN OR HYDROGEN. By PROF. A. V. HILL, M.A., Sc.D., F.R.S.

In vol. 152 of the *Zeitschrift für anorganische und allgemeine Chemie*, p. 342, 1926, Kautsky and Thiele describe a method of freeing a gas from oxygen by passing it through a porcelain filter candle into a solution of alkaline sodium hydrosulphite ($Na_2S_2O_4$). In order to complete the absorption of oxygen in a bubble as it rises to the surface, the bubble must be very small. This can be ensured by using a filter candle of material carrying a negative electric charge: in alkali the bubbles have a charge of negative sign on their surface and

are then repelled by the porcelain as rapidly as they are formed, so rising in a milk-like foam to the surface.

I have tried this method myself and found it very effective and convenient. A pound of hydrosulphite and a pound of soda in a few litres of water in a large bottle, holding a filter candle connected by a rubber pipe to a gas cylinder, is all that is required. Turning the cylinder on, a stream of gas is obtained from the bottle, in which, if the foam is fine, no trace of oxygen can be found by ordinary gas analysis. A continuous supply of gas entirely free from oxygen is often a great convenience in experimental work, and readers of the *Journal* may like to know how simple are the arrangements for its preparation. It should be noted that in order to keep free from oxygen the gas so prepared, it should not be allowed to pass through rubber pipes, which permit appreciable quantities of oxygen to diffuse through. Attention should be paid to the solution to ensure that it continues to absorb the oxygen.

DANGER OF EXPLOSION OF LIQUID AIR COOLED CHARCOAL TUBES, AND ITS PREVENTION. By JAMES TAYLOR, D.Sc., Ph.D., A.Inst.P.

It is not generally known that highly activated coconut charcoal, as used in physical technique for the clear-up of residual gases constitutes, with liquid air, a high explosive. Indeed, the method is used in some mines for coal blasting. Any failure or crack of a charcoal tube immersed in liquid air may, if the charcoal is sufficiently activated, result in a violent explosion. The writer has known an explosion of this kind which killed a man.

It is possible to avoid any danger of the liquid air coming in contact with the charcoal by surrounding the charcoal tube with a thin, fairly tightly fitting, metal tube. A few degrees of temperature may be lost in this manner, but there is no great danger in the case of failure of the inner glass.

A still better method is to utilise, instead of the charcoal, silica gel, precipitated from water glass. This is just as efficient as charcoal when activated, and there is no danger whatever on failure of the container.

A SIMPLE CONSTANT TEMPERATURE BATH. By PROF. A. V. HILL, M.A., Sc.D., F.R.S.

[*MS. received, 26th October, 1927.*]

Recently it has been required to maintain the temperature of a bath consisting of two or three litres of water inside a large Dewar flask as constant as possible for some hours, in order to obtain a stable base line when using a thermopile inside a glass chamber immersed in the water, to measure the production of heat by a muscle.

A resistance thermometer equipped with balancing leads was immersed in the bath and connected to a sensitive moving coil galvanometer, in such a way that, on a scale by which the observer sat for observation in the main experiment, 5 millimetres represented 1/1000 of a degree. The water in the bath was stirred violently by means of a stream of air supplied by a small Lennox blower. The bath was adjusted to be one or two degrees above the temperature of the room, and a nickel-chrome resistance wire inside a glass tube filled with liquid paraffin, and connected by leads to a 12 volt battery, was used as

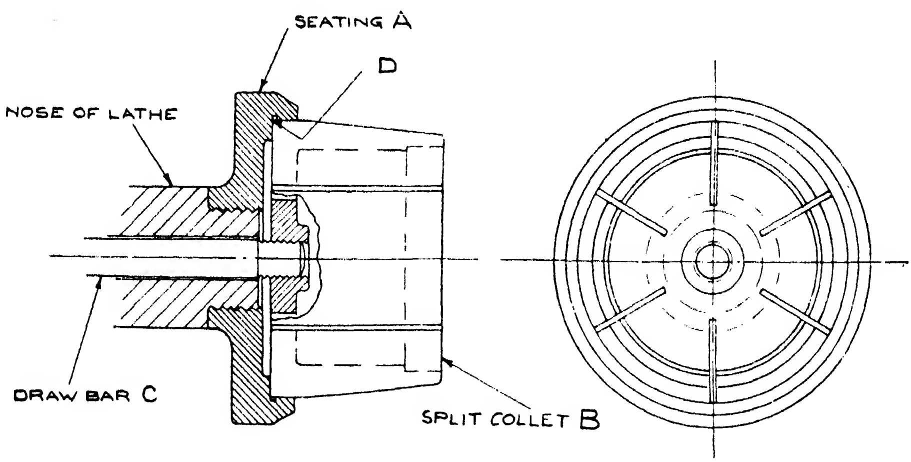
a heater. A pair of rheostats, one of high resistance shunting another of lower resistance, and a milliammeter, were placed in the circuit, the high resistance rheostat being employed as a fine adjustment.

By watching the spot of light the direction in which any change of temperature of the bath was occurring could be detected very early, and appropriate adjustment of the rheostats cause the change to be stopped and the spot of light to remain for long periods within one or two millimetres on the scale. Given that no rapid temperature changes occur in the room, observation and adjustment every few minutes are sufficient to keep the temperature constant within limits which should not exceed 1/2000° C. Only automatic arrangements of great complexity could produce such a constancy.

A SIMPLE SPRING CHUCK

THE sketch shows a simple type of spring chuck which was designed by this Company many years ago and which has proved very satisfactory indeed in use.

The chuck comprises a "seating" (*A*) which screws on the nose of the lathe and which is recessed to centre a "collet" (*B*). This is slit longitudinally, as shown, in six equidistant places and tapped to suit a draw bar (*C*) passed through the mandrel in the usual way.



The seating in (*A*) is counterbored so that when the draw bar is tightened, the back of the collet is drawn into this clearance space and the jaws are closed, by pivoting about their edges (*D*).

The collets may be of cast iron. They are cheap to make and can readily be bored out to suit any particular job. They should be made interchangeable as regards the outer diameter which centres in the seating, so that one seating will take a number of collets.

THE TAYLOR-HOBSON RESEARCH LABORATORY,
LEICESTER.

CORRESPONDENCE

THE CHATTOCK GAUGE

I OBSERVE that your November issue contains a letter from Mr John L. Hodgson with reference to my paper on the Chattock Gauge which appeared in the September issue. Mr Hodgson states that in my modification of the instrument changes of surface tension are balanced against changes of volume. This is not the case; and it is clearly stated in the paper that the object of the additional bulb containing oil is to secure balance among the additional hydrostatic pressures resulting from expansion of the liquids.

W. J. DUNCAN.

AERODYNAMICS DEPARTMENT,
THE NATIONAL PHYSICAL LABORATORY,
TEDDINGTON, MIDDLESEX.

A METHOD OF OBTAINING MONOCHROMATIC LIGHT

I SHOULD like to add, with reference to my Laboratory Note on "A Method of Obtaining Monochromatic Light,"* that further experience with the method shows that the size of powder suitable seems to vary with the origin of the soda ash, and that material coarser than 120 mesh is often more satisfactory.

J. DICKSON HANNAH.

ARGYLL, BLAIR ROAD, ALEXANDRA PARK,
MANCHESTER.

REVIEW

British Scientific Instrument Research Association. Ninth Annual Report

THE formation of the British Scientific Instrument Research Association, which took place immediately after the end of the war, was an important step in the history of British scientific instrument making, and its ninth annual report, which has just come to hand, gives a summary of its work for the past year which is of considerable interest. Owing to the constitution of this Association, which is largely supported by instrument manufacturers, only a portion of its results are made public, so that the report does not do full justice to its operations; but the items published give an idea of the importance of its investigations. Of the fifteen principal researches described, ten are of an optical character, as are also half of the specific manufacturing problems investigated, which would appear to indicate that the optical industry is more interested in research than the electrical and other branches of the instrument trade. These, however, have other facilities for carrying out investigations.

Dealing first with the optical researches, it has been found that the durability of the surfaces of microscope cover-glasses can be markedly improved by annealing, provided that it is effected immediately after the thin glass has been made. If even a few days elapse between the making and annealing, the latter process impairs the durability of the surface, instead of improving it. The design of an interferometer for the testing of microscope objectives has been completed after consultation

* *Journ. Scient. Instr.* 4 (1927), 427.

with Mr T. Smith, of the National Physical Laboratory, and its construction is to be commenced. A very important investigation has been carried out on the production of fused quartz lenses and the design of high aperture objectives for ultra-violet microscopy, including the design of ultra-violet objectives for achromation over a large range of wave-lengths. It is stated that the results aimed at have been fully realized in practice. Calculations have also been made for a monochromatic objective of 1·6 *N A*, intended especially for metallographic work, which is entirely free from zonal aberration. All this work has involved a thorough study of lens systems with varying parameters, and thirty-two systems have been examined, giving a large amount of information concerning zonal spherical aberration.

The investigations on the transparency of glasses to various parts of the visible spectrum have led to the evolution of an apparatus for measuring the reflection co-efficients of powders and papers for light of different colours, which is now being commercially manufactured. A report has been issued on barium oxide preparations and a considerable amount of work has been done on phosphorescent materials, especially on phosphorescent zinc silicate for use in cathode-ray oscillographs, which has now been made in a form which gives results considerably superior to any materials hitherto used. Four materials have also been found which give a yellow phosphorescence when bombarded with alpha particles.

The discoloration of glass when exposed to radiations has received a considerable amount of attention, and has been definitely associated with the presence of minute amounts of impurities. A comprehensive programme of research on this subject has been projected. The discoloration of the glass spheres of sunshine recorders has been investigated and a method of restoring them to their original transparency has been worked out. Optical homogeneity in glass has been investigated in collaboration with Mr F. Twyman; and the effects of grinding and polishing glass, using other liquids than water, have also been examined. Although it at first appeared that some of these liquids had advantages as regards the stability and durability of the polished surface, this has not proved to be the case in later tests.

Of electrical researches the principal related to moving coil ammeters and voltmeters, instrument control springs, and radiation pyrometers. A critical study of various types of moving coil instruments has been made, resulting in modifications of certain instruments. The investigations on control springs have been chiefly with a view to eliminating the sub-permanent set or temporary change of zero after prolonged large deflection, and various alloys have been experimented with. As regards pyrometers, an account of some of the work has appeared in an earlier number of this *Journal*, and a detailed report of the investigation has been issued to members of the association. Investigations have been conducted on photo-electric and selenium cells, various sensitive materials and residual gases having been employed for the former. It has not been found possible up to the present to produce selenium cells free from certain defects, but new designs have been developed and will be tested. The cause of corrosion of nickel anodes in electrolytic cells employed for the generation of hydrogen from potassium hydroxide has been investigated.

Among the specific manufacturing problems attacked have been the construction of level bubbles; transmission curves for optical and sextant glasses; investigation of glasses for producing sputtered mirrors; examination of experimental glasses for durability and special purposes; determination of the iron content of optical glasses; and measurements of refractive indices of liquids for ultra-violet light.

Inks for recorders; the effect of impregnating varnishes on insulating fabrics; of films for preventing the sticking of impregnated coils to winding formers; the causes of fracture of fine wires, and of the frosting of nickel surfaces when heated *in vacuo*, have been investigated; and tests have been made on X-ray apparatus and on transformer oils for use with such apparatus. Lubricants for gearing and slides of optical instruments have been studied and some special lubricants have been evolved.

Besides the specific researches mentioned in the report a considerable amount of work has been done in co-operation with other research associations. Some of the reports have been released for publication in this *Journal*, and it is to be hoped that others will follow shortly. The subjects dealt with are of great interest and industrial importance.

THE OPTICAL SOCIETY

At the meeting of the Optical Society on December 8th, 1927, at the Imperial College of Science, a paper on "The Design of Reflecting Prisms" was read by Instructor Captain T. Y. Baker, R.N. The author pointed out that in the majority of cases where reflecting prisms are used in optical systems there are nearly always great points of similarity of design. Reflections take place at angles of 45° with the surface; the planes of successive reflections are either the same or at right angles to one another. The reason seems to be that the designer-draughtsman has limited himself to these simple angles because they are easy to portray in plan and elevation on a drawing board, and that he has found himself debarred from using other systems through want of a practicable technique.

Captain Baker showed that any angles of incidence, and any alterations in the plane of reflection can be dealt with by the construction of a spherical diagram, which can either be drawn with ordinary drawing accuracy on the surface of a sphere, and then utilized to measure the various angles of incidence, etc., or if constructed more roughly, can serve as a diagram from which the various angles can be computed by spherical trigonometry.

From this diagram data can be derived which permit of the easy construction in wire of a model of the axial ray in its passages through the prism system. The next stage is to construct a wooden model of the full beam of light, using for the purpose either a cylindrical or a slightly conical rod to represent the full beam when passing through the lens system without the prisms. This wooden rod can be cut in a manner that is prescribed by the spherical diagram, and glued together again in an altered form. It then gives an exact representation of the passage of the full beam of light through the prism system. A further utilization of the spherical diagram permits of a wooden model being made of a prism which will give the necessary reflections to the full beam.

Among the prism systems examined was that used in the prism binocular. Captain Baker showed that the spherical diagram is necessarily based upon the choice of two points, one on each of two great circles on the sphere mutually at right angles. The distances of these points from the point of intersection of the two great circles is absolutely at the designer's choice. With the customary prism system both these distances are 90°. With the Abbé and Springer prisms one is 90° and the other 60°. Apparently a systematic examination of the prisms that would result from the choice of other angles has never been made, and the author suggested that if it were done possibly one might find a skew prism, of compact form and without re-entrant angles, that could be made in a single block of glass.

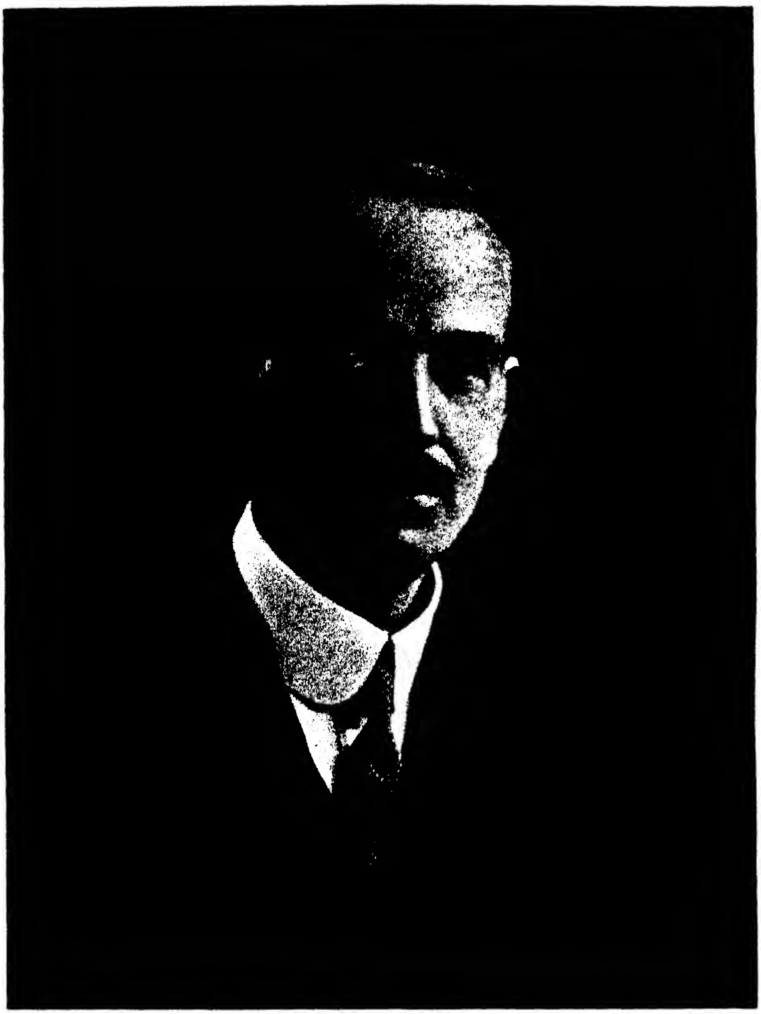
THE PHYSICAL SOCIETY

AWARD OF THE FIFTH DUDDELL MEDAL

The Council of the Physical Society has awarded the Duddell Medal for 1927 to Dr F. E. Smith, C.B., F.R.S. This medal is given annually for work in connection with the development of scientific instruments or of materials used in their manufacture.

Dr F. E. Smith's work at the National Physical Laboratory in connection with the development of electrical standards is too well known to require emphasis. He was trained at the Royal College of Science (1895–1900) under the late Sir Arthur Rücker, entering the National Physical Laboratory in 1900. There he formed one of the band of pioneers who, under Sir Richard Glazebrook, did so much to raise the scientific work of the institution to its present high level. His earliest work was concerned with modifications of the Wheatstone and

Kelvin Bridges for precise measurements of resistance, and the development of bridges for accurate platinum resistance thermometry. A classical piece of work followed on the current balance, by means of which it was found possible to evaluate a current of the nominal value of 1 ampere to within 1 part in 50,000. In the course of this work he developed the silver voltameter which bears his name, and which is generally accepted as the most reliable form of voltameter, in that there is no septem or envelope between the anode



Lafayette

Dr F. E. Smith, C.B., F.R.S.

and cathode. The successful development of the modern mercury-in-glass resistance standards is largely due to Dr Smith's work. His specification for the Weston normal cadmium cell is the one generally followed. It is now no uncommon experience for a batch of twenty standard cells to be made commercially in which the E.M.F. given by the cells agrees to one part in 10,000. Dr Smith was also responsible for the design of the Lorenz apparatus (the Viriamu Jones Memorial) installed at the National Physical Laboratory.

Dr Smith has also developed various magnetometers for the measurement of the magnetic intensity of the earth's field; one of his instruments now forms the standard for the measurement of the horizontal intensity at the Magnetic Observatory at Abinger.

In 1920 Dr Smith left the National Physical Laboratory to assume the position of Director of Scientific Research at the Admiralty. As President of the Physical Society (1923–1924) he acted as host to the large number of distinguished guests who attended the Jubilee Celebrations of the Society. He has consistently urged that progress in physics can best be accelerated by the introduction of new, or the improvement of old, scientific instruments. As one of the Honorary Secretaries of the British Association his organising ability is being devoted in a striking manner to the advancement of science.

EIGHTEENTH ANNUAL EXHIBITION OF THE PHYSICAL SOCIETY AND THE OPTICAL SOCIETY

At the time of writing the Catalogue is in print, and it is announced that the Eighteenth Annual Exhibition of the Physical and Optical Societies will be held on Tuesday, Wednesday and Thursday, January 10th, 11th and 12th, 1928, at the Imperial College of Science and Technology, Imperial Institute Road, South Kensington, and will be open in the afternoon from 3 p.m. to 6 p.m., and in the evening from 7 p.m. to 10 p.m.

More than eighty firms are exhibiting in the Trade Section this year, and in addition there will be a group of Research and Experimental exhibits by Fellows of the Societies, research laboratories and institutions, and others. Historical exhibits will also be included.

The Discourses in connection with the Exhibition, which will be given at 8 p.m. on each evening, are as follows:

On January 10th, Mr A. Whitaker, M.A., of The Gramophone Company, Limited. "Progress in the Recording and Reproduction of Sound."

On January 11th. Mr V. E. A. Pullin, B.A., O.B.E., F.Inst.P. "Recent Applications of X-Rays."

On January 12th. Mr J. W. T. Walsh, M.A., D.Sc., F.Inst.P. "Artificial Daylight."

We understand that the demand for tickets is considerably in excess of that in previous years, testifying to the increasing interest with which this annual event is regarded by scientific and general public alike. At the request of members of the societies, and to give them fuller opportunities of inspecting the exhibits, the Exhibition Committee has this year arranged a special morning session, admission to which will be restricted to members of the Physical Society and the Optical Society, by separate ticket. As in previous years the exhibition will be open to the public on the third day, without ticket.

ENLARGED EXHIBITION NUMBER OF THE JOURNAL

The issue of this *Journal* for February will be enlarged to 48 pages and will be devoted to the Exhibition of the Physical and Optical Societies. By permission of the Councils of the Societies it will contain full reports of the three discourses referred to above, and will include descriptions of the exhibits, specially written by members of the Editorial Committee and others. An innovation in the Catalogue this year is the introduction of asterisks to denote instruments shown for the first time at the Exhibition, an arrangement which should greatly assist the visitor and ensure that proper attention is given to new apparatus. An index is also given to the exhibits in the Trade Section.

INSTITUTE OF PHYSICS

PHYSICS IN THE FOOD INDUSTRY

THE thirteenth lecture of the series "Physics in Industry" was given to the Institute of Physics on November 14th by Sir William Hardy, M.A., F.R.S., Director of Food Investigation at the Department of Scientific and Industrial Research.

In his lecture Sir William Hardy gave the audience a broad survey of a fascinating branch of applied physics, namely, that in the food industry. He pointed out that the purely thermodynamical aspect of the subject of refrigeration had been put on a sound basis by the early work on the physical properties of refrigerants, and the chief need on the technical side at the present time was for more information concerning small refrigerating plants, particularly those of the absorption type using silica gel or charcoal.

Heat transmission problems had been investigated at the National Physical Laboratory, and some remarkable phenomena discovered in connection with the transfer of heat by convection. There the thermal conductivities of insulators were also receiving study. He pointed out that our knowledge of humidity control of the atmosphere in cold stores was inadequate, and certain foodstuffs, particularly eggs, demanded close adjustment of the humidity to a pre-determined value. To clear up some difficulties which had arisen in connection with the brine spray method of humidity control, an investigation was in hand at the National Physical Laboratory to determine the influence of various factors such as size of drop, air speed, etc. on the efficiency of this method.

Another problem receiving consideration was the transmission of heat from a stream of air to pipes carrying cold brine or other refrigerating fluid. Whilst the simplest case of the transmission from a metal pipe to a gas was understood, but little was known as to the influence of snow deposits and of the shadowing effect when a number of pipes were packed together.

The lecturer then passed on to a consideration of the physico-biological problems of refrigeration. He pointed out that the object of refrigeration was to produce in the stored foodstuffs a path of change as close as possible to the normal curve and with end points acceptable to man. Living matter is a system in continuous change, and when dead does not cease to change, even if we exclude bacterial effects. The generally accepted view was that death resulted in a breakdown of structure and in the release of catalysts. It seemed almost certain that all catalysts had not the same temperature coefficient, so that it was not possible to obtain the same results in foodstuffs from a protracted period in cold storage as from storage for shorter periods at normal temperatures. The desirability of uniform temperature conditions for highly organised structures had resulted in the development in mammals of the equivalent of a thermostat, hence it was to be expected that a large change in temperature resulted, not only in a retardation of senescence but also in a disturbance of the balance between the various reactions.

Freezing had been of only limited use in the preservation of foodstuffs; it was only in the case of mutton, of some fish and of butter, that it could be said to be really a success. The freezing and thawing of beef results in "drip," carrying away proteins in solution and the red pigmented haemoglobin. Some colloidal materials were destroyed by being frozen, and such an effect was noticeable in the case of milk. A great deal had been learnt concerning the phenomena from the study of temperature-time curves. Generally speaking, the more rapid the rate of cooling the smaller the "plateau" on the curve and consequent separation out of the water as ice.

Another factor to be considered was the lower limit of temperature to which the material was carried. Eggs, for example, when fresh froze at a temperature of $-0^\circ{\cdot}65$ C. and at $-0^\circ{\cdot}45$ C. when old. If, however, the temperature was lowered beyond -6° the yolk was permanently affected and, on thawing out, became a hard pasty mass.

Further researches on frog's muscle had shown that if desiccation did not proceed beyond a certain critical point, the muscle recovered its normal characteristics on immersion in weak salt solution, and the critical point of direct desiccation and the critical death temperature of freezing were isotonic.

PARTICIPATION OF THE ROYAL METEOROLOGICAL SOCIETY

AT a Special General Meeting of the Institute of Physics held on December 16th, and on the recommendation of the Board, the Royal Meteorological Society was admitted a Participating Society of the Institute.

The Royal Meteorological Society is the sixth society to co-operate in the scheme of participation, and an important step is thus taken towards the realization of one of the principal objects of the Institute, as expressed at its foundation, namely, to co-ordinate the work of all existing societies concerned with the science of Physics and its applications. The action which the Royal Meteorological Society has taken will be welcomed by the members of the Institute and of the other Participating Societies, to whom, no less than to the members of the newly-admitted Society, the considerable benefits of the scheme are further extended.

JOURNAL OF SCIENTIFIC INSTRUMENTS. BACK NUMBERS

TWO shillings per part will be paid for clean, undamaged copies of parts 1, 2, 4, 11 and 12 of Volume 1 of the *Journal*. These should be sent to the SECRETARY, INSTITUTE OF PHYSICS, 1 LOWTHER GARDENS, EXHIBITION ROAD, LONDON, S.W. 7.

TABULAR INFORMATION ON SCIENTIFIC INSTRUMENTS

A FEW sets of the separate tables remain, and may be obtained on application to the SECRETARY, INSTITUTE OF PHYSICS, 1 LOWTHER GARDENS, EXHIBITION ROAD, LONDON, S.W. 7, at a cost of 5*s*. per set. The sets contain eighteen tables, and are complete except for Table II: British Photographic Lenses, which is out of print.

LABORATORY AND WORKSHOP NOTES

READERS of the *Journal* are reminded that notes concerning laboratory or test-room methods, and workshop devices or methods of utility to instrument-makers are welcomed, and that ten shillings will be paid for each such note published.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V FEBRUARY, 1928 No. 2

THE EIGHTEENTH ANNUAL EXHIBITION OF THE PHYSICAL AND OPTICAL SOCIETIES

THE annual exhibition of scientific instruments organised by the Physical and Optical Societies has become one of the great scientific events of the year, and each renewal of the occasion shows a decided step forward in the number of exhibitors and the interest taken in it. Large as is the accommodation of the Imperial College, the exhibition is encroaching more and more upon it, and even overflowing into the corridors. When one considers the relatively small size of the scientific instrument industry, it is remarkable how it is able to muster such a large display of novel and costly exhibits; and one cannot help feeling that if the whole of British industry showed the same energy and progressive spirit as is manifested by the scientific instrument manufacturers, the prosperity of our country would soon be satisfactory. It is doubtful whether any other nation could rival the display which has just been made at South Kensington, and every one who attended it must have been impressed with the high quality of British scientific instruments.

It cannot be said that this year's exhibition has brought forth any features of epoch-marking or even striking novelty, but those who are seriously interested in the quality and development of scientific instruments must have found ample scope for their attention, and satisfaction of their requirements. Many material advances in electrical instruments, both of the laboratory and commercial types, were manifested, of which perhaps the developments in apparatus for radio frequency measurements and radio apparatus in general were most striking.

Great interest was naturally shown in the latest forms of short-wave receivers and in the long-distance press receivers exhibited by the Marconi Company, and in the high power transmitting and rectifying valves shown by the Mullard Radio Valve Company, as well as in the four-electrode and screened grid valves which are now coming into general use. The developments in the older types of measuring instruments, though less spectacular, were no less important, a particularly attractive item being the new switchboard oscillograph of the Cambridge Instrument Company, which shows a P.D. and current wave on a small ground glass screen, using a single vibrator and a metal filament lamp.

In optical instruments the great advances of a few years ago have settled down to steady development, and there was little of striking novelty to mention; the chief improvements being in projection and ophthalmic instruments. Nautical and surveying instruments are going through a stage of material improvement in accuracy and detail, the chief points being the substitution of micrometers for verniers, and the adoption of optical devices for simultaneous reading of different parts of the scale, for eliminating centring errors.

The research section continues to be a most interesting one, and the chief contribution this year was from the Research Laboratories of the General Electric Company, who showed their methods of rating metallic filament lamps by the use of photo-electric cells, and also

some new forms of such cells specially sensitive to the red end of the spectrum. Their new vacuum switches, with tungsten contacts on springs with soft iron armatures in vacuum tubes, which can be operated by external solenoids, were one of the most valuable novelties in the exhibition, and if they can be extended to the inclusion of a delicate moving coil or other relay movement in the tube they will probably inaugurate a new era in reliable sensitive relays. The new form of ferric chloride wet cell shown by Mr A. M. Codd, which has some features in common with the Féry type of Leclanché cell, seems to have many good features; and the apparatus for ultra-violet microscopy and refractometry exhibited by Dr L. C. Martin, and the portable illumination photometer and other instruments shown by the National Physical Laboratory, were all of great interest.

In the historical section a remarkably interesting exhibit, illustrating the development of weighing instruments from early Egyptian times, was made by Messrs W. and T. Avery, Ltd., from their Historical Museum; and was one of the most complete exhibits of the history of an art which has ever been made. Professor Andrade showed some illustrations of the early history of the air-pump, and Dr Ferguson exhibited several astrolabes and other mediaeval instruments. An ultra-modern touch was given to this section by the Research Department of the Gramophone Company, who showed a series of gramophones, from the earliest to the latest types, with graphs of their performance; a modern sound box with its equivalent electrical diagram; and a standard source of sound with Rayleigh disc.

As on former occasions various members of the editorial executive and others have kindly consented to inspect and describe the various sections of the exhibits. An important innovation in this year's catalogue of the exhibition was the marking of those exhibits which were shown for the first time, and the writers have been asked to deal principally with these novelties.

As usual a lecture was given on each day of the exhibition, and especial interest was shown in the first of these, by Mr A. Whitaker, M.A., of the Gramophone Company, on "Progress in the Recording and Reproduction of Sound." Mr Pullin's lecture on "Recent Applications of X-rays," and Dr Walsh's on "Artificial Daylight" were also greatly appreciated, and by the kindness of the lecturers and courtesy of the Physical and Optical Societies we have been able to reproduce these lectures in this *Journal**.

The value of this annual exhibition cannot be rated too highly. Not only does it enable scientific workers in all branches to have an opportunity of inspecting the various types of instruments and keep themselves informed as to their progress, but it certainly breeds a most healthy spirit of emulation among the various firms who find themselves in close contact with their rivals and able to judge of their progress. The eagerness of each manufacturer to have as many novelties to show as possible, and the chagrin of those who had little new to show and their determination to do better next year, was most marked, and there can be no doubt that the exhibition is playing an enormous part in stimulating the industry to its best efforts.

As on former occasions the organization of the exhibition was most excellent, and the great brunt of it, as well as the preparation of the excellent catalogue, has this year fallen on Mr T. Martin, the energetic Secretary of the Institute of Physics. All those who have visited or taken part in the exhibition will join with us in congratulating him on the result of his efforts. The valuable assistance of Mr C. T. Archer, of the Imperial College, must not be overlooked. Our thanks are also cordially tendered to those gentlemen who have furnished us with the descriptions of the exhibits.

* The Discourse on Artificial Daylight, by Dr J. W. T. Walsh, is unavoidably held over to the March number of the *Journal*.

PROGRESS IN THE RECORDING AND REPRODUCTION OF SOUND. By A. WHITAKER, M.A.

A DISCOURSE GIVEN ON 10TH JANUARY 1928, AT THE EIGHTEENTH ANNUAL EXHIBITION OF THE PHYSICAL AND OPTICAL SOCIETIES

THE nature of sound was appreciated in very early times. Aristotle (*De Audibilibus*) was satisfied that the sensation of sound is conveyed to the ear as disturbances of the air, and it had been shown that any body that was emitting sound was vibrating. The contrary fact, that certain sounds would excite vibrations in some bodies, must also have been obvious, but the first graphical records of these vibrations were obtained in 1864, when the Phonautograph of Scott and of Koenig was invented.

The Phonautograph consisted of a light membrane carrying a stylus which made a trace on a lamp-blacked surface. Under the influence of sound the membrane vibrated, and if the record surface was moved in a direction at right angles to the direction of the stylus, a wavy trace was made, which bore some relationship to the character of the exciting sound. No attempt was made to reproduce the sound. Crude horns were used to concentrate the sound on the membrane, and, the function of a horn not being understood, parabolic reflecting surfaces were at first used, whilst later conical and other curiously shaped structures were found to give better results.

In 1877 Edison obtained sound records with a device very like the Phonautograph, but instead of using a lamp-blacked surface, the stylus was caused to indent a tinfoil or waxed paper sheet. The peculiar advantage of this arrangement was that, if the stylus was caused to re-traverse the sheet, the vibrations communicated to the membrane gave rise to sound, and the sound was a recognizable imitation of that employed to make the record. Later Bell improved the Edison phonograph and produced records on wax cylinders. Bell found it advisable to use separate recording and reproducing machines. The recording stylus was sharp and was mounted on a stiff diaphragm, while the reproducing stylus was rounded and the diaphragm relatively limp. By this device the quality of reproduction was improved and the life of the records greatly lengthened. Edison further improved the design, and produced a commercially successful talking machine. The diaphragm was of glass, and the pitch of the screw cut on the records so fine that reasonably long items could be recorded. The records were duplicated by an electrotype process and were cast in wax.

At this stage in the development of the cylinder machine or phonograph, the first disc machine or gramophone made its appearance, the inventor being Berliner. The physical principles employed differed in no way from those of the Edison and Bell machines, but the mechanical details were entirely different, and reverted to some extent to those of the Phonautograph. The record was not a series of depressions but a wavy groove. The recording machine was essentially a phonautograph, and the stylus scratched a trace through an etching ground on a metal plate. This was "bitten in" with acid and the record played with a fine needle point, which tracked in the groove and communicated its transverse vibrations to a diaphragm. It was also found possible to use electrotype moulds, made from the original wax discs, as dies to press records of a thermoplastic composition.

For about thirty years after the invention of the Berliner gramophone the development of both the disc and cylinder machines was slow. Larger models were built, and by slow processes of trial and error the volume of sound given out was increased, while the quality was greatly improved. Many mechanical improvements were introduced, but the essential element of acoustic design was practically lacking. Most machines were but refined forms

of either the Edison and Bell phonograph or the Berliner gramophone. In both types the essential was a diaphragm, to which the vibrations on the record were transmitted and which formed one side of an enclosed space, the sound-box. In another part of the sound-box a hole communicated with the horn. In the horn some progress was made empirically, while the function of a horn was still disputed. Early horns were conical. Later a flare was fitted to the large end of a conical horn, and finally a horn flared throughout its length became the usual practice.

During this period certain distinctive side lines of development were initiated. An interesting invention was due to Parsons, who, in 1904, exhibited a sound-box working on the principle of the siren. In this sound-box the emission of compressed air from a series of orifices was controlled by a member connected to the reproducing needle. This type of machine carried the usual type of horn and developed into two commercial machines, the Auxetophone and the Stentorphone. Descriptions had appeared of machines abandoning the conventional sound-box and horn, and phonographs were made in which the reproducing stylus was carried on the apex of a large conical paper cone. This principle, in an ingenious form, appeared later as the Lumière pleated paper diaphragm machine. This type of machine gave good results and effected a welcome saving in space, but it was unlucky in appearing just before great theoretical advances were made in the design of the conventional type of gramophone.

During and after the War telephone technique advanced rapidly, and the accurate methods of measurement developed were applied to the talking machine. For the first time it became possible to plot with accuracy the frequency response curve of a gramophone—the efficiency of reproduction at each acoustic frequency.

Immediately the defects of response became apparent, efforts were made to correct them in different ways. The earlier semimagical formulae were abandoned and definite progress was made. Deliberate resonances were introduced in the gramophone system to fill up gaps in the response, and prominent peaks were tracked down by laborious trials to different resonant components, and steps taken to eliminate them. Considerable success was attained, but the method is laborious and full of uncertainties, since an attempt to introduce or suppress a single resonance often alters the characteristic at other frequencies, and the relationship between cause and effect may be obscure.

With the knowledge resulting from the development of telephony many workers also endeavoured to perfect systems of electrical recording in order to take advantage of their increased convenience and flexibility. Mechanical recording such as had hitherto been used in practice must be subject to great limitations, since the amount of power available is so small that in any attempt to modify or correct it by purely acoustic means it will be so attenuated that it is no longer sufficient to drive the recording diaphragm. Even with little or no deliberate correction the performers had to be grouped inconveniently closely round the recording horn.

In an electrical recording system the components need not be efficient from the power point of view, and so this consideration can be sacrificed to the all-important quality, evenness of response to all frequencies within the range it is required to record. In general in any electrical recording system the sounds are picked up by a microphone, the output amplified by thermionic amplifiers and passed on to a recording mechanism. There are several practical recording systems, and one outlined by Maxfield and Harrison* was developed by the Western Electric Company of America. This system uses a condenser microphone and amplifiers which had already been developed to a high pitch of perfection in connexion with telephonic work. A very important part of any recording system is the actual recording mechanism which cuts the groove on the wax disc.

* *J.A.I.E.E.*

It is necessary to have a recording mechanism which possesses the characteristic that for equal input energies at any frequency the maximum velocity of the cutting stylus is constant, the amplitude of vibration varying inversely as the frequency. Nearly all electromagnetic devices, such as telephone receivers, have definite resonances which cause extremely prominent peaks in their response characteristics. Maxfield and Harrison described a recording mechanism which has no prominent resonances and which, being designed by analogy with an electrical filter system, is accordingly relatively efficient.

Velocity in a mechanical vibrating system is equivalent to current in an electrical network. Stiffnesses represent capacities, their magnitudes varying inversely. Masses represent inductances and non-reactive loads resistances. In deriving the equivalent circuit of any mechanical device, a stiffness between two consecutive moving members is represented by a shunt capacity and between a moving member and a rigid support, a series capacity. By deliberately proportioning the parts of a mechanical system it can be made to behave as an equivalent electrical network, and hence the peculiar properties of filter circuits can

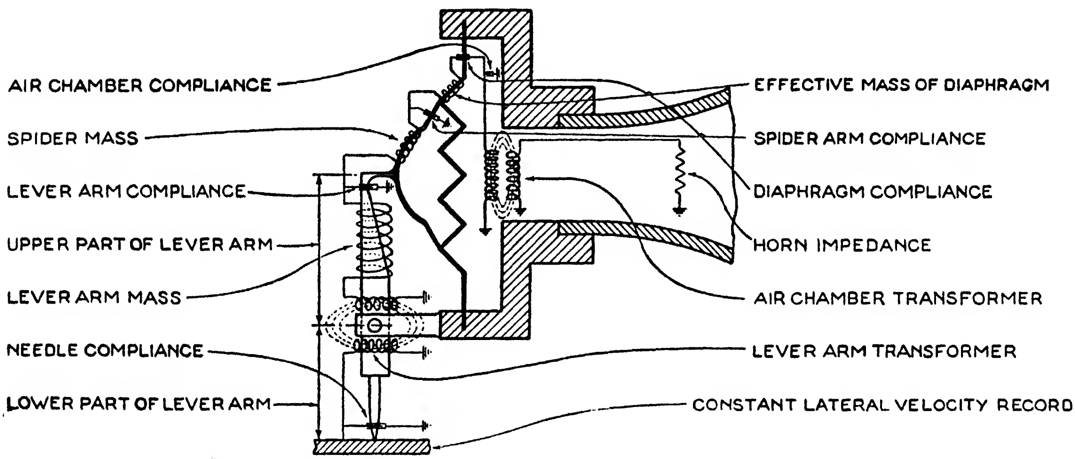


Fig. 1. "His Master's Voice" No. 5 Sound-box

be simulated. A great difficulty in designing these systems is the lack of satisfactory non-reactive mechanical resistances. In the Maxfield and Harrison design the load consists of a rubber rod along which the vibrations travel torsionally with heavy attenuation.

The frequency characteristic of this recording system is a horizontal, approximately straight line from 250 cycles to 5000 cycles. Below 250 cycles it is made to fall away regularly since, the amplitude varying inversely as the frequencies, there would be a danger of one groove encroaching on the next if a loud sound at a low frequency were recorded at its natural strength. Above 5000 cycles and below 50 cycles it cuts off abruptly.

The practical advantages of electrical recording are very great. The electrical oscillations can be transmitted over telephone lines, so that performances in any convenient hall can be recorded in a central office, with the best possible conditions at both ends of the line. It has been found possible even to mount a complete recording equipment in a special lorry, which can go out to places otherwise inaccessible and lay field lines to considerable distances. Performances of all kinds that would otherwise be lost are recorded in this way.

Gramophones also can be designed by applying the analogies between electrical and acoustic systems.

Fig. 1 shows a diagrammatic section of a sound-box designed as the mechanical equivalent of a filter circuit. Superimposed on each component the equivalent electrical component is shown; while in Fig. 2 the equivalent circuit is set out, together with the ideal band-pass

filter circuit. In an ordinary band-pass filter circuit any section through the centre of the series impedances divides the filter into two parts, the impedances of which, looking forward and backward from the line of section, are matched. In this sound-box two transformers are used, the needle arm with its lever action and the ratio of areas of diaphragm to horn opening. Each of these steps up the velocity (which is equivalent to current), and hence in usual nomenclature would be described as a step-down transformer. The matching of impedances by equivalent transformers is one of the chief points in the design of this sound-box.

The impedance of the horn constitutes the terminal load, and a well designed horn is necessary if its impedance is to be sensibly independent of frequency. It has been pointed out how horns evolved from the reflector on the phonautograph to the flared horns of the gramophones designed a few years ago. When electrical recording made it possible to

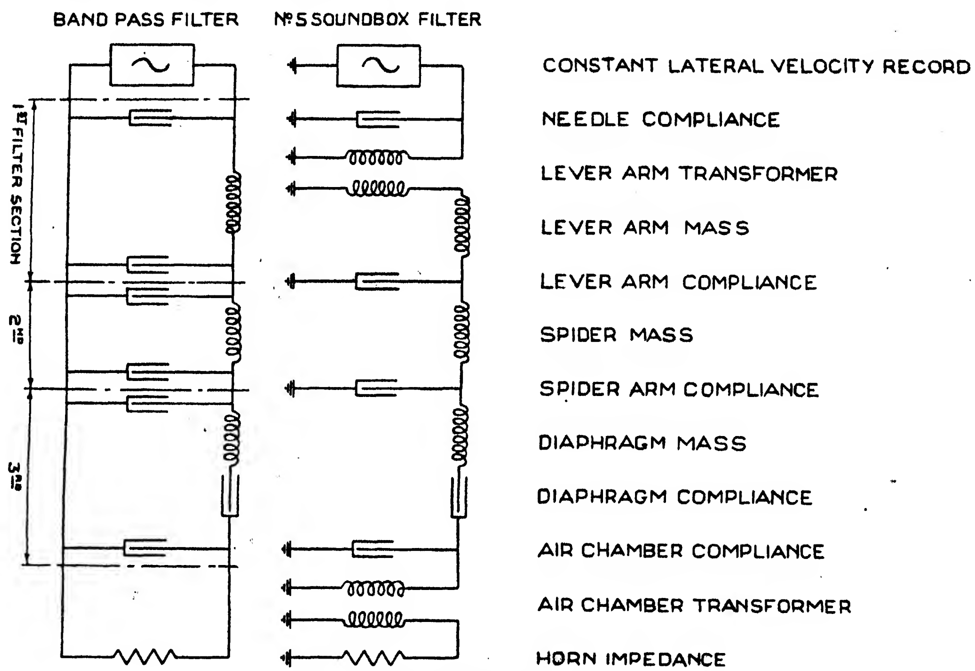


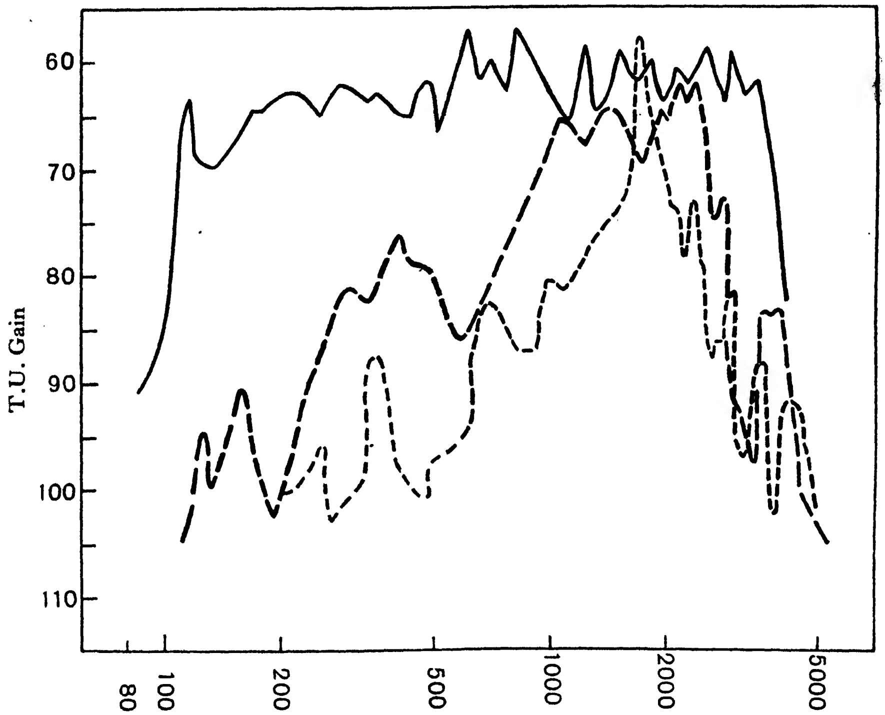
Fig. 2. (After Maxfield and Harrison)

obtain records of comparatively low frequencies, great efforts were made to improve the response of the gramophone in the bass and take full advantage of this advance. Hanna and Slepian had shown that the exponential horn was the ideal form, and sound-boxes were adapted to exponential horns by cut and try methods, though the principle of "matched impedance" was not at that time formulated. The results were so promising that the exponential horn was adopted, and at once raised the quality of reproduction to a considerable extent. When deliberate and more correct matching was later employed, the improvement was even more pronounced.

The great length of an exponential horn necessitates folding it within a cabinet, and at once several problems arise. The law of an exponential horn is that its cross-sectional area shall be an exponential function of the distance along the axis. In a folded horn the distance along the axis becomes a quantity difficult to define. So also does the cross-sectional area. In practice folded horns are designed on many additional assumptions, all intended to bring them into a definite relationship with an equivalent straight exponential horn. None of the assumptions is rigorously sound, but it has been possible to produce folded and

divided horns of complicated construction of which the characteristic properties approach those of the ideal exponential form.

Recently a new type of talking machine has been developed, the electrical reproducer. In this case all the components of the gramophone have gone excepting the record. The reproducing needle is now attached to a pick-up which converts the mechanical vibrations directly into electrical oscillations, which are amplified and feed loud-speakers. Good amplifiers are available, pick-ups with good characteristics are not exceptionally difficult to design, and correcting networks can be embodied to modify the frequency characteristic, but the greatest difficulty is in the loud speaker. There are not many loud speakers that can approach a good modern gramophone for truth of reproduction. Many components



Gramophone 1897 shown - - - - Gramophone 1912 shown — — — Gramophone 1928 shown ————

Fig. 3

are now sold as separate units, but the highest quality is probably shown in certain outfits that are designed as a whole, and of these two are worthy of mention. The Panatrope uses an electromagnetic pick-up and a Rice-Kellogg loud-speaker. The "His Master's Voice" Electrical Reproducer also uses an electromagnetic pick-up, but a loud-speaker of a new type consisting of a large diaphragm of aluminium alloy foil, stretched almost to its elastic limit on a frame and driven by a coil placed eccentrically. Most loud speakers show well defined interference patterns which vary with frequency; hence at some points in their sound-fields some frequencies will be deficient and others too prominent. The stretched diaphragm loud speaker, suitably mounted, has a good characteristic and generates substantially spherical waves, so that interference effects are avoided.

Fig. 3 shows the frequency response curves for three gramophones of the conventional type. The oldest is a Gramophone Co. model of 1897, with massive moving parts and a

short conical horn. The second is a 1912 model. Many refinements had been effected and a large flared horn fitted. The third is a 1928 cabinet model, designed according to electrical analogies as the equivalent of a band-pass filter. In this diagram the abscissae are frequencies plotted on a logarithmic scale and the ordinates represent the gain or amplification required to bring the output up to an arbitrary energy level. These are plotted in transmission units, which are defined as $10 \log_{10} E/E'$, where E is the energy output and E' is a standard energy level. The transmission unit scale is roughly proportional to the audible value of the sound. Three T.U.'s represent a noticeable change in intensity.

Extension of the range of reproduction of the gramophone is still desirable. At the lower end of the scale it becomes difficult to radiate efficiently without the use of huge horns or unwieldy baffles. At the upper end of the scale another consideration arises. Surface noise or scratch is due to the shock excitation of the gramophone system by minute irregularities in the record surface. This gives rise to sound which is spread over a band of frequencies, and this sound spectrum has a maximum in the upper register. If the range of reproduction be extended upwards, surface noise is considerably increased, while the gain in tone is only very slight.

Many attempts are being made to record sound photographically, and the subject is such a large one that it is impossible to do more than indicate briefly the lines along which developments are proceeding.

Sound is picked up with a microphone and the amplified oscillations caused to modulate a beam of light or a source of light. Several effects are known which enable this to be done with apparatus that contains no moving parts. The Kerr electro-optical effect, the Faraday magneto-optical effect, and the light emitted from a vacuum tube have all been applied with a measure of success to the photographic recording of sound. In all cases the record is made on photographic film and usually consists of a band of varying photographic density, though some early methods employed a band of constant density and variable width. For reproduction a light sensitive cell is used, with amplifier and loud-speakers. Selenium and thallium oxy-sulphide (thallofide) cells have been used, but suffer from time-lags which cause severe attenuation of the high frequencies. Photoelectric cells are generally used, but the amplification required under practical conditions is enormous.

One other point of interest has recently arisen in connexion with the gramophone. It has always been known that gramophone records become scratchy and harsh after a considerable number of playings. Microscopic examination shows this to be due to disintegration of the record material, and also brings to light remarkable aspects of record wear. In most cases some notes are selectively worn, and the wear shows itself in a series of patches, distributed regularly along the groove, whose phase relation to the record wave varies from one case to another. This is due to the fact that the load is not purely resistive but contains reactive components which vary with frequency and are out of phase with velocity. A well designed gramophone system puts a heavy load on the record and gets a high acoustic output, but the reactive component is small and the wear is actually less than that due to the old type gramophone with a very much smaller volume.

A pick-up takes far less useful work off a record than a sound-box—of the order of one-hundredth usually—and so the wear due to a pick-up should be relatively small. Actually it has been found that the wear due to nearly all pick-ups is excessive and that it is surprisingly difficult to design a pick-up to give low wear. The trouble lies in the effective absence of a load on a pick-up. The needle is mainly constrained by a series of masses and stiffnesses, which introduce purely reactive and damaging forces on the record. Damping is added, but it is very difficult to obtain non-reactive mechanical damping, and in practice it never approaches the resistance value of the useful load in the case of an ordinary gramophone. It has been found possible to construct a non-reactive pick-up by careful design,

and comparative tests show that whereas ordinary pick-ups wear a record 30 per cent. more on an average than an ordinary sound-box, the wear due to a non-reactive pick-up is almost negligible. In this, as in so many cases, the gramophone owes much to the theory derived from analogies between mechanical and electrical systems.

The original work on which rest many recent advances in the recording and reproduction of sound was done largely by the Western Electric Company of America, the Bell Telephone Laboratories and the staff of the Research Laboratories of the Gramophone Co., Ltd. The author's acknowledgments are due to the Gramophone Co., Ltd., for permission to give this lecture and to embody in it their technical information.

RECENT APPLICATIONS OF X-RAYS. By V. E. PULLIN, O.B.E., F.INST.P. Director of Radiological Research, Research Department, Woolwich.

A DISCOURSE GIVEN ON 12TH JANUARY 1928, AT THE EIGHTEENTH ANNUAL EXHIBITION OF THE PHYSICAL AND OPTICAL SOCIETIES

I PROPOSE to give a short outline of the scope of the work, together with one or two examples, of the Radiological Research Laboratory at Woolwich.

The work of the laboratory originated with a suggestion, made during the War, that X-rays should be used to examine the bases of shells for flaws which were at that time causing considerable anxiety to those responsible for shell production. It was very soon realized that if X-rays were to become available in a practicable manner for this sort of work, a general research, not only in the realm of technique but also concerning the improvement of all the types of X-ray apparatus, was very necessary. We therefore planned a scheme of research that should embrace the improvement of X-ray tubes, particularly with regard to their operation at extremely high potentials, and also the improvement of the necessary electrical apparatus. We also envisaged a study of the technique involved in high power metal radiography, and the methods to be adopted in the radiography of all types of inanimate objects.

During the last year of the War practical results were obtained from this new development which were of the greatest value, and many problems were successfully tackled by X-rays that could have been dealt with by no other method. Immediately after the War it was realized that the progress already achieved amply justified an intensive prosecution of this research, and the programme was added to, both in particular and in general.

One of the branches of the research which received special attention was that pertaining to crystal analysis and X-ray spectroscopy. It was obvious that many problems confronting the Fighting Services were particularly suitable for attack by the new methods developed by the Braggs, Debye and Scherrer, Hull, and others. Many such problems, though of the greatest interest from the X-ray spectroscopy point of view, are of course of a strictly secret nature, and, as such, are unsuitable for public discussion; it will be realized that they deal very largely with explosives. The investigation of the physical structure of explosives and the properties dependent upon it form the very basis of Service scientific research. Not only explosives, but many metals used for Service requirements also afford an extensive field for investigation by the X-ray spectrometer. Examples which occur to me are gun steels and the effect of heat treatment and mechanical working; the structure of electrically deposited metals, which is now assuming such an important aspect; and the survey of many of the alloy systems. All these problems have been dealt with at Woolwich and have benefited to a large extent by the employment of X-ray methods. At the present time there are three X-ray spectroscopic laboratories in my Department which are constantly fully occupied.

With regard to other aspects of the work, it has been found possible not only to perfect X-ray technique so that comparatively large metal specimens may be radiographed, but further, it has been possible to reduce this technique to a simple drill which, combined with specially designed apparatus, has enabled the use of the rays for radiography to be extended beyond the research laboratory into the dockyards and factories of the Services.

In the early days of the work, it fell to the lot of my Laboratory to examine by X-rays a large number of Service stores of all descriptions, and as the properties of the rays became more generally known, suggestions and experiments were thrust upon us from Government departments all over the country. In course of time it was realized that this general work was altogether outside the scope of the Research Department. Arrangements were therefore made whereby X-ray plant was installed in various factories and routine work undertaken by the men on the spot. The work of the Research Department is now confined to developing suitable technique for any particular class of job, reducing it to its simplest possible form and designing and making the specially modified plant that is called for in each particular instance. Electrical transformer design has received attention, and specifications have been drawn up embodying the conditions necessary for the factory use of X-rays. Such transformers must be robust; they must be capable of being moved with ease and without risk of damage and, lastly, they must be capable of continuous running at constant output.

With regard to the development of X-ray tubes for high voltages, it was very soon realized that there was a limiting voltage (about 300,000) beyond which it was not practicable to construct a hot cathode X-ray tube on conventional lines. This branch of the research therefore was reconsidered and a still more elaborate programme has been drawn up which is now receiving practical attention. The factors involved in the realization of a really high voltage tube are wellnigh innumerable, and it was thought that the only true solution of the problem lay in a complete investigation of each particular factor by itself and in its relation to others. It is in this way that the question of larger high power tubes is now being tackled.

Apropos of this, I should like to remark that the question of the *necessity* of extremely high voltages for metal penetration has received the most careful consideration. In the first place, we have to face the fact that if we can examine very heavy ingots by X-rays—I mean something in the nature of 6 to 8 or even 10 inches in thickness, for example gun forgings, and show the position and extent of flaws in them—the method would unquestionably have the greatest possible value, not only to Service work but to engineering generally. This state of affairs, however, is impossible at present. The greatest thickness of steel that can be penetrated by X-rays in a practical manner is about $4\frac{3}{4}$ inches. Incidentally I might remark that in 1917 the maximum penetration that could be achieved was 1 inch of steel. I shall have a little more to say in a moment concerning the policy of further research in extremely high voltage X-rays.

I will now refer to one or two specially designed X-ray installations which have been designed and constructed in my Laboratory. They are in actual use in various Government departments.

(1) *Veterinary set*. This apparatus is installed in the Army Veterinary College at Aldershot. It has been very generally and successfully used since its installation. It has assisted very considerably, especially in conditions such as "ringbone," where clinical diagnosis presents great difficulties in the early stages. Major Pryor of the Army Veterinary School tells me that in one particular case a very valuable horse sustained an accident whilst steeplechasing and acute lameness developed. It was impossible to assign the cause from clinical examination. X-ray examination speedily revealed the origin of the trouble, suitable treatment was applied and the patient made an uneventful and perfect recovery.

(2) Small portable X-ray set on wheels which is installed at the Royal Aircraft Factory at Farnborough. This set is designed so that it may run under the wings of aeroplanes in order that they may be examined for broken spars and other defects without the necessity for stripping the wing.

(3) A 200,000 volt X-ray plant which is installed in Portsmouth Dockyard. This set is of a semi-portable and compact nature and is entirely self-protecting. It has been designed more particularly for the examination of welds. Up to ½ inch in thickness these may be examined visually, usually on top of the set. Small periscopic screens are used for this purpose. For greater thicknesses, radiographs are taken either below or in front of the set.

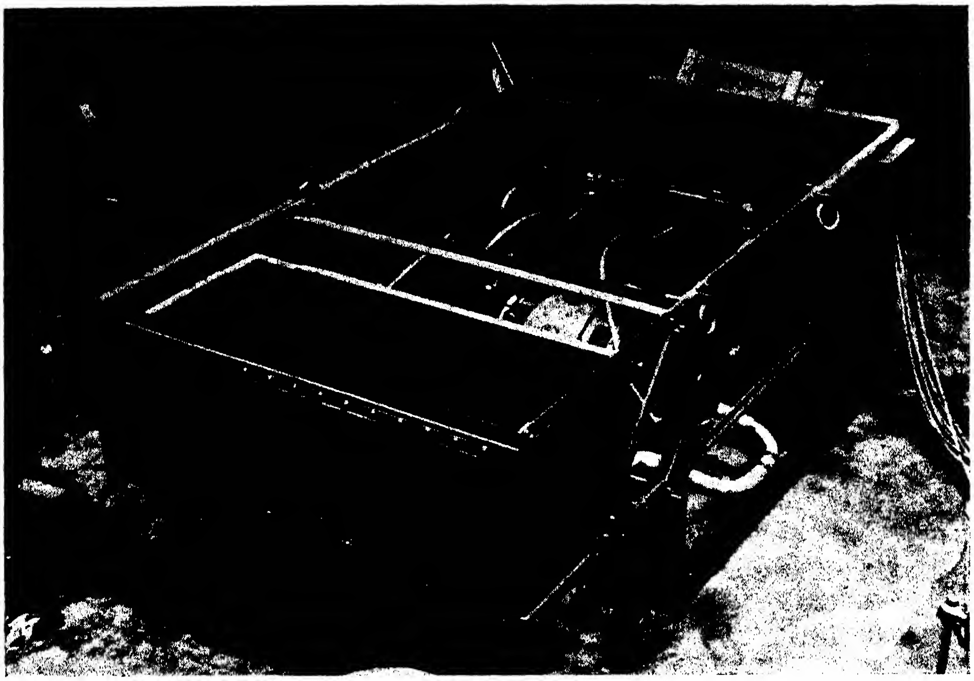


Fig. 1. 200,000 volt semi-portable X-ray plant

X-rays are an infallible guide to the soundness of a welded joint. Typical radiographs obtained are shown (Fig. 2). Flaws which reduce the strength of the joint by 10 per cent. are very obvious on the radiograph.

(4) An X-ray installation in one of the Government Inspection Departments for the routine examination of fuzes. This machine is capable of examining on an average about 500 fuzes per hour.

(5) 400,000 volt X-ray set installed in the Research Department, Woolwich, for experimental radiography.

I may now refer briefly to typical objects radiographed in the Service. In one case no difficulty was experienced in examining a locomotive tyre 4 inches in thickness; a hole ⅛ inch diameter drilled into it was clearly seen. Castings are radiographed both to ensure that the material is sufficiently sound to withstand the stresses it may be called upon to bear, and also to ensure that no blow-holes are situated where machined surfaces are required.

Forgings may contain fine pipings, as Fig. 3 shows. A particularly interesting object radiographed was a cylinder some 23 feet long. In this case considerable expenditure had been incurred before a mark was noticed on the inside of the cylinder. The fault was

examined stereoscopically and its extent determined. It was sufficient for the cylinder to be condemned. The cost of further work upon the cylinder was saved. Aluminium wheels are examined for blow-holes and "cold-shut." This interesting type of flaw is apparently due to the cooling of the gas within a cavity, molten metal flowing in and solidifying as a pellet, nearly filling the cavity.

The use of X-rays for the examination of welds, castings and forgings, both as an adjunct to metallurgical research and also as a method of routine inspection, has now become general in the Services, but we cannot yet deal with the thickness of metal that is desirable. Clearly more penetrating rays are urgently called for. This means X-ray tubes operating at higher voltages. The questions arise—How far are we justified in planning and developing research on such tubes?—Will the result of our work yield the desired efficiency?

From consideration of Compton's theory of X-ray scatter it has been suggested that if voltages are increased for the purpose of realizing additional penetration, the amount of scatter that will reach the film will be so enormously in excess of the amount of undeviated radiation that all contrast will be obliterated by the resultant photographic fogging.

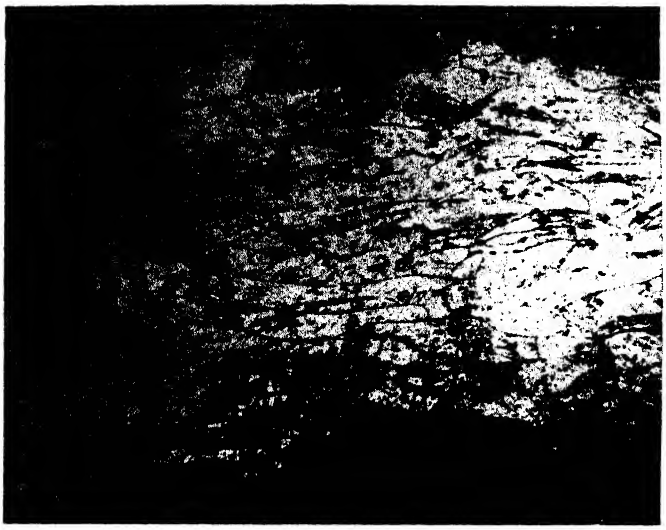
This question, having such an important bearing on research policy, has been investigated at Woolwich by my colleague Mr A. G. Warren, both from a theoretical and also an experimental point of view. It has been shown that when radiographing a block of steel 3 inches in thickness with a voltage of 200,000 volts, only one part in 2500 of the *incident* radiation reaches the film. Practically the whole of radiation is scattered. Of this scattered radiation about 1 per cent. reaches the film, but this 1 per cent. of general scattered radiation exceeds the direct image-forming radiation some 25 times. Under such adverse conditions, however, photographic contrast is marked and has definite practical value.

The practical investigation turned in the first place upon the efficiency of diaphragms. Radiation passing through 1 inch or 2 inches of steel was allowed to fall on a photographic film (*a*) directly, (*b*) through a lead tunnel some 12 diameters long. In the second case practically only undeviated image-forming radiation reached the film, whereas the radiation reaching it in the first case included the scatter. By adjusting the times of exposure in the cases (*a*) and (*b*) for equal density of film it was possible to determine the relation between the undeviated and the scattered radiation.

The next aspect of this question to be investigated was the effect of the elimination of scattered radiation on photographic contrast. It is easy to show that for short exposures, such as are commonly used at present in metal radiography, the elimination of scatter has very little effect upon the photographic contrast, although the negative is a very much thinner one if the scatter is eliminated, due, of course, to the fact that much less intense radiation is operating. On the other hand if the time of exposure is increased to give the same density the contrast ratio increases greatly when scattered radiation is eliminated. Thus it is clear that for thick metallic specimens at high voltages an efficient method of eliminating scatter—an efficient diaphragm or grid—is an essential element in technique.

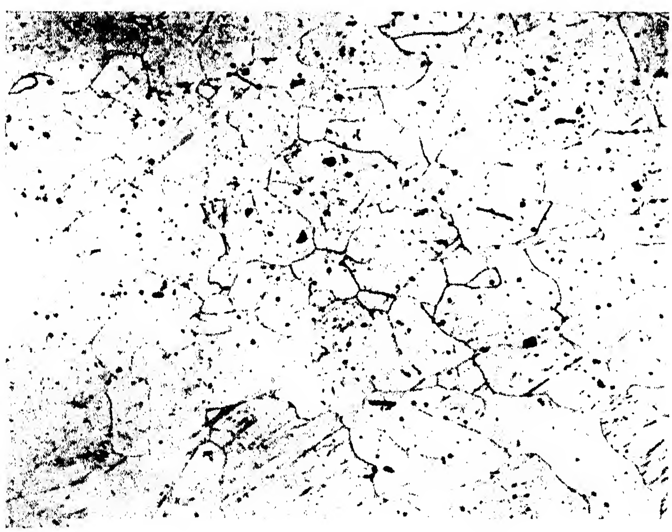
I have already mentioned that when radiographing 3 inches of steel at 200 K.V. about twenty-five times as much scatter as incident radiation reaches the photographic film, and that the contrast in the radiograph is perfectly practicable. This scatter is incident at all angles upon the film. Compton has expressed the manner in which the scatter from a thin foil is distributed. The distribution becomes more uniform as the thickness of the specimen is increased. It is easily demonstrated experimentally that although the total amount of scatter reaching the film may be very large, that reaching it from any particular direction is very small. If therefore a suitable grid diaphragm is used, only a very small fraction of the scatter can reach the film in addition to the unscattered image-forming beam. With the usual forms of single diaphragm the scatter incident upon the film may be about 10 per cent. of the total scatter, but with a double diaphragm it may be reduced to about 1 per cent.

Now, if we assume for the sake of argument that at infinitely higher voltages the total amount of scatter reaching the film is a maximum—that is, some 50 times greater than that experienced under the conditions I have named—then, since the efficiency of properly constructed grid diaphragms is such that this figure may be reduced to something of the



Magnification 50 times

Fig. 4



Magnification 50 times

Fig. 5

order of 1 per cent., the conditions at exceedingly high voltages with grid diaphragms are better than those now experienced at 200 K.V. without their use. Unfortunately, infinitely high voltages, from the point of view of X-ray production, are not at present available, but radiographs of a $3\frac{1}{2}$-inch block of steel at 300,000 volts show an enormous increase of contrast when a grid diaphragm is used.

I will now refer very briefly to some of the work that we are doing in the realm of X-ray crystal analysis. I have already indicated the type of problem which is normally submitted to me. It is not possible to mention some of the more interesting work we have done because, as I have said, it concerns secret investigations about which I am not allowed to speak. I may say, however, that although the properties of explosives very largely depend upon their minute structure, yet this structure is so far unknown in many cases and forms the basis of many investigations. I am able to show you one or two illustrations that I think may be of interest, indicating the direction in which this work is of value in the Services.

Figs. 4 and 5 are photomicrographs of a broken test piece of Armco Iron. Fig. 4 shows the appearance of the strained crystals under the microscope, while in Fig. 5 the crystals show no sign of deformation. Figs. 6 and 7 are typical Debye-Scherrer spectrograms of the same test piece, and they illustrate very graphically the persistence of orientation of the crystal units, although the corresponding photomicrographs show no deformation of the crystal boundaries. It may be that this technique will prove of considerable value in engineering for the purpose of detecting small permanent strains in metal for which microscopic evidence is inadequate. X-ray evidence in similar cases is now being considered at Woolwich side by side with the corresponding conventional metallurgical evidence.

Spectrograms of rolled copper show that the crystals are definitely oriented. On heating, the orientation disappears. Further heating results in growing of the crystals.

Different methods of electro-deposition of nickel give entirely different crystal arrangements, indicated by X-ray spectrograms. In one case the crystals are arranged quite at random. With another method one set of crystal planes is parallel to the plane of deposition. Clearly the physical properties of the deposit will depend very largely upon the crystal arrangement and thus X-rays have great value as an adjunct to research in electro-deposition of metals.

Cellulose gives a characteristic crystal spectrum, whilst nitrocellulose is amorphous. The presence of the cellulose lines in a spectrum of supposed nitrocellulose indicates that nitration is not complete.

It is well known that the two modifications of iron, α and γ, have different crystal forms, α iron being centred cubic and γ iron being face centred cubic, and so each modification yields a characteristic X-ray spectrogram. In certain alloys the retention of the γ modification is highly undesirable. The γ iron is unstable and there is a slow secular change to α iron, which is accompanied by a change in volume which may produce cracking. It will be seen from Fig. 8 that the presence of γ iron may be at once recognized in the spectrogram. Experiments are now in progress to adapt this method to give quantitative results.

Rolled steel again gives a typical spectrogram indicating orientation. On heat treatment the orientation first disappears and crystal growth supervenes. A particular case of interest in which spectroscopic methods were applied was a steel cylinder which had been subjected almost instantaneously to an extremely high temperature on the inside. Some 400 spectrograms were taken with a view to discovering whether any regular orientation pattern could be obtained. It was found, however, that evidence of such orientation was fairly local and yield was by no means symmetrical.

The investigation of the structure of some compositions is rendered very difficult because they may be available only in very minute crystals. For the examination of calcite a crystal measuring $1 \times \cdot 7 \times \cdot 3$ mm. was used, and of potassium permanganate a crystal $2 \cdot 9 \times 1 \times \cdot 85$ mm., which yielded excellent spectrograms. Of a particular explosive substance the largest crystal which could be obtained had dimensions of only $\cdot 4 \times \cdot 2 \times \cdot 16$ mm., yet with this small crystal quite a reasonable spectrogram was obtained.

For spectrum analysis a very special type X-ray tube is in use at Woolwich. The design

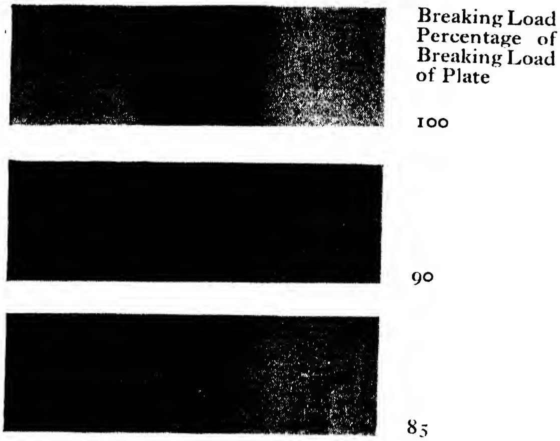


Fig. 2. ½″ Butt Welds

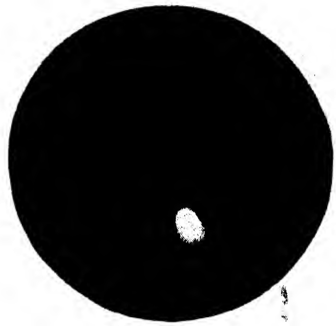


Fig. 3. Forging containing pipings

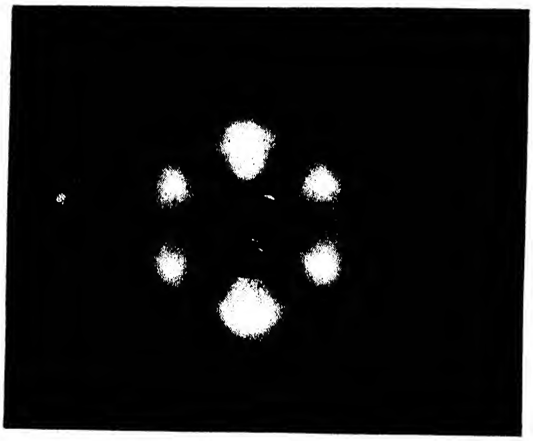


Fig. 6

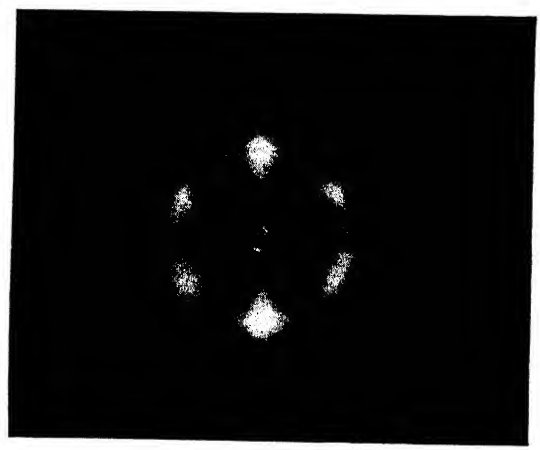
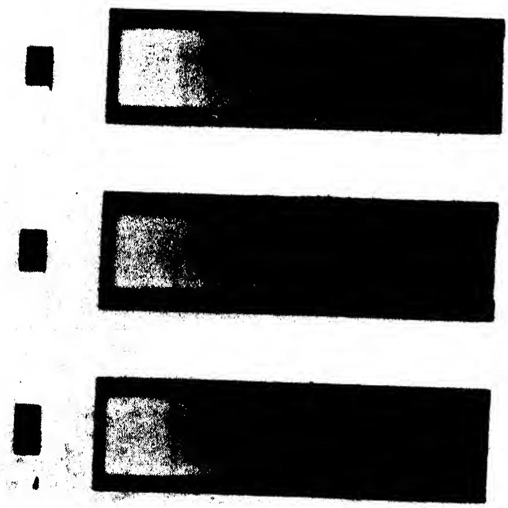


Fig. 7



is largely due to my colleagues Mr F. W. Osborne and Mr A. R. Greatbatch. The points of advantage about it are its stability, adjustability and the fact that it yields a truly line source of X-rays.

The main activities of the Radiological Branch of the Research Department have been included in this very cursory review. The point to which I should like to draw your particular attention is the eminently practical value of Radiological Research in ordinary technical progress. It is this aspect of the subject which occupies our whole attention at Woolwich. Fundamental research for its own sake is no part of our function. We seek to apply radiology in every way in which it can be thought to advance the work and interests of the Services either immediately or ultimately. Bearing our object in mind, I may say that we have no reason for anything but a feeling of perfect satisfaction with the practical results of our work.

DESCRIPTIONS OF THE EXHIBITS

RESEARCH SECTION. By ALLAN FERGUSON, M.A., D.Sc.

The Exhibition organized annually by the Physical and Optical Societies is now in its eighteenth year. Each year sees a marked increase in the number of the exhibits, an increase which shows no signs of falling off. Already their magnitude is such as to tax to the utmost the electrical supply of the Imperial College, and it is quite probable that a few years hence the Department of Physics will be too small to house the Exhibition. With increasing numbers of the exhibits comes a corresponding increase in their variety and interest, and the present commentator, who is by habit a sparing and infrequent cultivator of exhibitions, found that the interest never flagged from first to last. Indeed, his one cause for complaint is that three days is all too short an allowance of time in which to make a thorough study of exhibits of such interest and importance, and he looks forward to the not far distant time when the Exhibition will be held over a period of four or even six days—if the good nature of the authorities of the Imperial College of Science will permit so long drawn an invasion of their peace.

In the Research and Experimental Section, with which this article is concerned, the exceedingly varied nature of the field over which Physical Science spreads its interest was the outstanding and dominating feature. Woollen research and primary cells; the energy content of high explosives and a new form of thermionic voltmeter; an apparatus for the measurement of the efficiency of Paul Pry* cheek by jowl with a new form of vacuum switch; the reflex micrograph hard by a dynamometer which records the variation in the draw-bar pull of a plough; these, to quote but one or two from the large number of exhibits in this section, show sufficiently well how physical principles enter into, not the engineering sciences alone, but so venerable an art as agriculture, so young a science as experimental psychology.

The steady success of the Exhibition is sufficient reason for its continued existence. Were other justification necessary it is to be found in this very fact that the rapidly increasing variety of application of physical principles and ideas makes it almost impossible for any one person to keep in touch with these applications without some such concentration as an exhibition implies. The experimental psychologist may not know—may not care to know—what is going on in the gas trade. None the less his own work, which every year requires apparatus of growing complexity of design, may well benefit by the study of the

* Exhibit A 8, No. 8.

appliances used in gas measurement; and the gas engineer will certainly be the better for a study of photometric and allied measurements carried out under strictly controlled psychological conditions.

Writing as one who is specially interested in the researches which are in progress in pure physics, the present writer feels that the one serious criticism which may be made of this section is the very small part taken in the Exhibition by the research workers from our academic laboratories. Research work in these laboratories is, in general, carried out in conditions very different from those which obtain in technological laboratories large or small. And while the student of pure physics gains many valuable ideas from the study of the exhibits from research laboratories in applied science, he naturally desires to see a little of the trend of research in pure physics in laboratories other than his own; while the technological worker might even find something refreshing and stimulating in the *ad hoc* assemblage of apparatus to which lack of facilities too often condemns the researcher in a university laboratory.

In brief, it is in offering a common ground for the meeting of different minds, and for the interchange of ideas that an exhibition such as this is fulfilling its highest function; and the writer is voicing more than a pious aspiration when he expresses a strong desire to see at later exhibitions research in pure physics occupying a position comparable with that taken up by the remarkable examples of technological research to be seen in this section.

Seventeen groups showed forty-nine exhibits, and every exhibit had its points of interest and value. It is impossible in the space allotted to describe these various items critically and the task of selection is difficult; indeed it was not possible in the time at one's disposal to inspect every exhibit on the list. It must not be inferred, therefore, that the space spent on the description of any one exhibit measures anything more than the present writer's interest in the topic or the amount of time which he spent at that particular stand.

MR G. L. ADDENBROOKE has carried out an exhaustive series of experiments on dielectric attraction in electric fields. If a point electrode be attached to one terminal of a Wimshurst machine and held vertically over a dry liquid dielectric a conical hollow is produced in the liquid under the conducting point; if the field is made intermittent by using an induction coil, a spark gap being inserted in the circuit to nullify the make potential, very striking effects are produced, which may readily be projected on to a screen. A series of small splashes may be seen radiating outwards from a centre immediately beneath the electrode, the area in the immediate neighbourhood of the centre being but slightly disturbed. The effect is attributed to ions of like sign to the electrode which, being violently repelled, impinge on the surface and shoot outwards and downwards, producing splashes which have the appearance of shallow grooves on the surface, radiating outwards. The phenomena, which are capable of wide variation, are influenced by the shape, sign and distance of the electrode, the nature of the dielectric, and above all by moisture. They are readily reproduced and will well repay careful examination.

MR OWEN AVES exhibited an anatomical trial frame for presenting ophthalmic lenses before the eyes which represents a considerable advance on the ordinary frame, providing as it does precision controls for the various movements possible.

In his Deviograph the patient, on placing his head in a definite position fixed by means of a chin-rest, sees with one eye a magnified virtual image upon a screen of a target consisting of eight small circles symmetrically disposed around the edges of a rectangle. By means of a stylus he marks out on a concealed chart the apparent position of the circles as seen by the other eye. The process is then repeated, interchanging the rôles of the eyes. The author points out that the usual prismatic corrections incorporated in a prescription may prove in daily use uncomfortable and on occasion intolerable, in great measure owing to

the difficulty of the tests. The charts give definite quantitative results for the muscular imbalance in eight principal para-central zones and the instrument can be used equally well on adults, children or illiterates.

The British Research Association for the Woollen and Worsted Industries showed some half-dozen interesting exhibits.

A most effective simple stroboscope was shown in the shape of a vertical disc mirror kept in rapid rotation about a diameter. A beam of light reflected from the mirror sweeps round the room in a horizontal plane, and when properly synchronized with the objects under observation shows them as if stationary. The spindles on a spinning frame were thus exhibited. Particularly interesting was the breaking into drops of a fine water jet. The shadows of the drops were projected on to a screen, the Plateau spherule and the oscillations of the drops being easily observable. The mirror is driven by means of a tape passing over a vertical cone on the axis of the mirror and a bobbin on a parallel axis near by. A fine adjustment may be made by screwing the bobbin up or down so as to raise or lower the tape on the cone.

It is now known that ordinary tests of the effect of light on dyed fabrics have little value unless the atmospheric conditions are properly controlled. Humidity especially has a very pronounced effect, and the fugitometer, which is a series of small vertical chambers arranged round a central lamp, permits of the exposure of the patterns under constant and controllable conditions of humidity, as the humidity of the chambers can be altered at pleasure by the use of special solutions in the humidifier.

Light rich in ultra-violet rays has proved specially useful in textile analysis. A special chamber is provided in which objects exposed to ultra-violet radiation may be examined. Materials which in ordinary light require close inspection to differentiate between them stand out quite prominently in ultra-violet light. In particular, oil stains on fabrics, mildews, cottons in different degrees of mercerization may easily be distinguished in light of this quality. Fibre comparators and automatic fibre stretchers were also shown. Altogether a thoroughly interesting section. The writer hopes that the Shirley Institute will be moved to send to next year's Exhibition a section which will let us learn something concerning recent advances in the cotton industry.

The Brown-Firth Research Laboratories provided an exhibit which demonstrated very clearly the rapid progress made in the production of alloy steels for specific purposes. It is not very long since the present writer exposed a stainless steel knife on the roof of the Manchester College of Technology. A few months were sufficient to leave the specimen in a very melancholy and rusty state, but the specimens of non-corrodible steel exhibited in this section seem quite capable of permanently resisting even the acid vapours of a Manchester atmosphere. Some of the steels have remarkable properties, a specimen of heat-resisting crown steel being shown at 800° C. under a permanent stress of 8000 lbs. per square inch. Finished articles made of these steels take a beautiful and permanent lustre and apart from their use in the heavy industries there appears to be a future for such steels in articles for domestic use.

Mr A. M. Codd has devised a new form of single-fluid primary cell which seems to be clean and constant in action. The liquid is an aqueous solution of ferric chloride contained in a glass jar with lid, the positive electrode consisting of two or three rods of carbon hanging from the lid, the negative electrode being a flat disc of amalgamated zinc lying at the bottom of the vessel. The zinc electrode is protected on open circuit by the zinc chloride which is formed in its neighbourhood. If the cell is to be left for long periods on open circuit it is advisable to cover the zinc electrode with a layer of sand or powdered pumice. This of course raises the resistance of the cell, but prolongs its life. The resistance of a three-pint

cell is of the order of an ohm; the voltage-time curve of such a cell, discharging through 10 ohms external resistance, shows a rapid fall from about 1·5 to 1·35 volts, a slower fall to about 1·25 volts which is reached at about 150 hours, then a very slow gradient indeed until at about 450 hours, when the gradient increases, the cell falling from a little over 1·2 volts to 1·1 volts in the period 450–600 hours, after which the cell rapidly collapses. Taking the mean potential difference on a 10-ohm external circuit as about 1·22 volts it will be seen that the capacity of the three-pint cell is about 70 ampere-hours—corresponding to about 34 ampere-hours per pound of ferric chloride used. The temperature-coefficient of the cell is not mentioned.

THE FUEL RESEARCH BOARD of the Department of Industrial and Scientific Research exhibits a standard apparatus designed to give comparative values for the velocity of reaction of coke with carbon dioxide. Three values of the reactivity of any given coke are recorded, (*a*) the initial reactivity, (*b*) the reactivity when freed from residual volatile matter, (*c*) the (constant) reactivity obtained by the prolonged action of carbon dioxide on the coke. The figures so obtained for blast furnace coke, gas coke, and low temperature coke are notably different and are significant in connexion with the purpose for which the coke is intended.

The reactivity values are obtained by heating a known volume of sized coke to 950° C. in a silica tube, treating it with nitrogen, passing carbon dioxide at a constant rate and measuring the volume of gas insoluble in caustic potash, which is obtained from a known quantity of carbon dioxide.

The mercury vapour trap exhibited by PROFESSOR G. I. FINCH depends on the fact that mercury vapour is absorbed by a liquid alloy of potassium and sodium. Sodium by itself possesses this absorbing power, but the alloy used is much superior to sodium inasmuch as it retains its efficiency for a long period of time. The efficiency of the alloy was clearly shown by running two similar vacuum tubes on equal voltages, one being directly connected with a pump and the other through the trap. The vacua, as measured by the lengths of spark gaps in parallel with the tubes were in the ratio 1 : 12.

The exhibits of the RESEARCH LABORATORIES OF THE GENERAL ELECTRIC COMPANY cover a remarkably wide field and it is impossible to do more than to select one or two of the exhibits for discussion.

A photoelectric rating machine for electric lamps (Fig. 1) was neat in design and rapid and simple in action. It consisted of a table turning about a vertical axis round the circumference of which were disposed a number of lamps with the bulbs turned downwards. Below the table is a pair of photoelectric cells connected in series, one a sodium cell, the other a rubidium cell. The lamps are brought in turn over this pair of cells, the ratio of the currents in the cells being determined by the spectral distribution of the light of the lamp and being independent of its intensity. Hence if the currents through the cells are equal when the cells are exposed to a certain lamp, they will be equal for any other lamp emitting light of the same colour. The equality of the currents is indicated by the zero deflection of an electrometer.

An interesting exhibit was that of a new type of photoelectric cell sensitive to the extreme red. Light dispersed by a spectroscope may be thrown alternatively on to a normal potassium cell or a red-sensitive cell. The current is measured by a "ticking" electroscope (a carbon filament on a gold leaf hinge which discharges against a carbon rod). The potassium cell may be shown in this way to be insensitive to light of wave-length greater than 600 $\mu\mu$, while the new cell responds to light of about 750 $\mu\mu$.

A simple method was also shown by means of which a photoelectric cell may be used with very simple apparatus to detect weak illuminations. The current through the cell is

driven by a potential which is greater than the sparking potential and is limited by a thermionic valve. The current therefore flows intermittently and gives clicks in a telephone connected in the circuit. Light of *very* low intensity, when incident on the cell, diminishes the frequency of the clicks or stops them altogether.

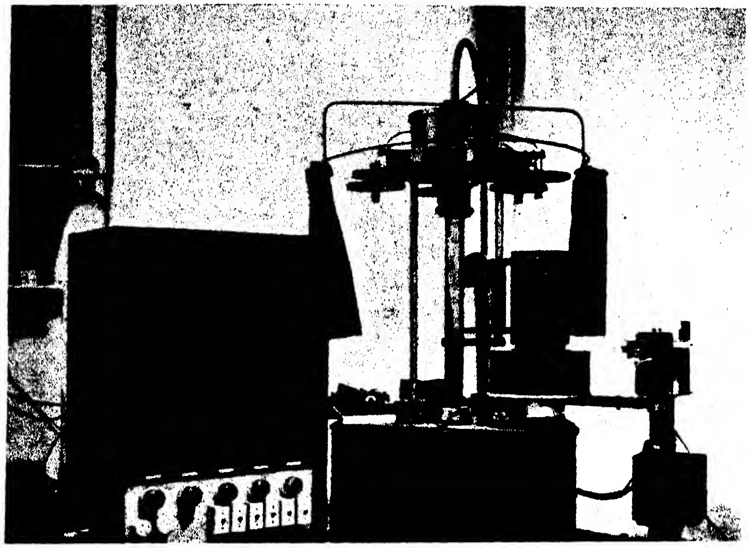


Fig. 1. Photoelectric Rating Machine

A "glimpse" apparatus, which measures the least time necessary to discern a given object has been designed for the investigation of visibility in artificially lighted streets. A vertical disc mirror has its surface divided into some six or eight sectors, one of the sectors being replaced by a piece of plane glass. The mirror is capable of revolution about a horizontal axis, and an observer looking along this axis and through the unsilvered sector sees a view of a model of a "real" street. If he looks at a silvered sector the view is obscured, but a plane mirror placed between his eye and the disc, and at an angle of 45° to the axis of rotation of the disc enables him to see an actual model of a "dummy" street which is at right angles to the "real" one. In this way his eye remains accommodated and adapted. If a fixed mirror is now placed behind the disc mirror and at right angles to the disc's axis of revolution, the observer, as the disc revolves, will see only the "dummy" street. Remove the fixed mirror, and he will then catch occasional glimpses of the "real" street through the unsilvered sector. The experiment consists in adjusting the speed of the mirror until the observer is just unable to detect changes made in the disposition of articles in the "real" street as compared with the "dummy" street.

Space will not permit of more than the bare mention of some of the remaining exhibits in this section, interesting though they may be. An X-ray camera of special design built to fulfil a number of different requirements deserves, however, more than passing mention.

The Research Laboratories of Messrs Adam Hilger, Ltd., exhibited an experimental apparatus, designed at the suggestion of Professor Kerr Grant, for demonstrating the high frequency interruption of light by a piezo-electric crystal.

A section of a quartz crystal cut parallel and perpendicular to the electric axis was mounted between crossed Nicol's prisms, a wedge being inserted to compensate for rotatory dispersion. The crystal, whose frequency of vibration was determined by its dimensions, was maintained by a valve circuit. When stressed it permits light to pass through, and an

interrupted beam is therefore transmitted, and falls upon a mirror rotating about a horizontal axis with a frequency of 132 revolutions per second. The streak of light thus produced is divided into bands whose distance apart forms a measure of the frequency of the interrupted light beam. In this manner the frequency of the beam was determined as 168,800 cycles per second, the frequency of the crystal as measured by an absorption frequency meter being 84,500 cycles per second.

The Technical Optics Department of the Imperial College of Science and Technology exhibited a series of instruments and apparatus for ultra-violet work in microscopy, refractometry and spectroscopy. The demand for increased resolving powers in biological and metallurgical work focusses interest on methods which make use of ultra-violet light. Thus, for example, the use of radiation of wave-length 0·275 μ permits of a resolving power double that attainable with the green light of the visible spectrum. The story seems simple when told, but the adaptation of instruments to radiation of such short

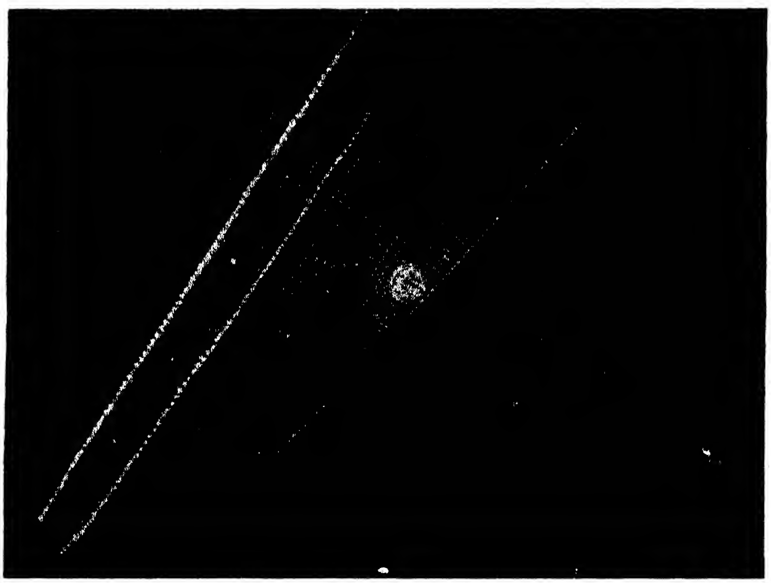


Fig. 2. *Navicula Rhomboides* × 2000. In ultra-violet radiation, $\lambda = \cdot 275\,\mu$

wave-length has involved the facing of mechanical and technical difficulties of a high order, and the department is to be congratulated on the manner in which these difficulties have been attacked and surmounted. An example of the work is shown in Fig. 2. It is interesting to note that instructional courses in ultra-violet microscopy are to be given in the Technical Optics Department, commencing in March.

The Soil Physics Department of the Rothamsted Experimental Station had two exhibits, each of outstanding importance. The problem of designing a balance which shall record continuous changes of weight, which shall be sensitive, and which shall give open readings on a chart of reasonable dimensions is one which will appeal to workers in most branches of physical science.

Attempts have been made to solve the problem by devising a mechanism for dropping, and for recording the time of dropping a small ball on to the pan of a balance, whenever the balance is out of equilibrium by a definite known amount. This process is however essentially discontinuous, and the Oden-Keen automatic recording balance, by combining this process with an electromagnetic control which records the changes in position of the

balance beam between the successive additions of the equal weights, makes the process a continuous one. One has, therefore, on the same chart, a compact record of the behaviour of the balance between the addition of successive weights.

The electromagnetic control is provided by the attraction between a vertical magnet attached to the balance pan and a solenoid surrounding the magnet. By suitably (and automatically) adjusting the solenoid current the varying weight may be balanced, the changes in the solenoid current being taken as a measure of the variation of the weight on the other scale pan. The balance is used at Rothamsted for the study of problems involving the determination of the distribution of differently-sized particles in various suspensions, evaporation problems and the like, but the wide range of application of such an instrument is obvious.

Their second exhibit was a dynamometer designed to record the variation in the draw-bar pull of a plough at work. A "hydraulic link" unites the plough and the tractor. The interior of the link is connected by means of a hollow copper spiral to a slightly curved Bourdon tube, the near end of which is fixed, the farther end free to move. The link, spiral and Bourdon tube are oil-filled; and changes in the pressure in the oil due to the changing stresses in the hitch of the plough cause motion of the free end of the Bourdon tube. This motion is suitably magnified and is recorded on a moving celluloid ribbon. The curves so produced are afterwards integrated by means of a planimeter. It is evident that the stress-changes at the plough-hitch are dependent on a large number of variable factors—the force necessary to overcome the cohesion of the soil, the force necessary to turn the cut slice into its final position, frictional forces on the different parts of the plough—all these enter into the final record on the film. It nevertheless seems possible to obtain numbers which are significant in expressing the behaviour of different types of soil. Soil physicists will find the method and results of great interest; and one can imagine that a modern psychologist would be equally interested in recording the varying emotions of the ploughman!

Mr E. B. Moullin had on view two new forms of high range thermionic voltmeter, one a pivoted multi-range instrument of resistance two megohms and reading to a maximum of 120 volts. The other instrument was of similar type reading peak and mean values up to a maximum of 500 volts.

The National Physical Laboratory showed a simple but very effective projection of the circular fringes produced by a Fabry and Perot interferometer; an electric furnace with devices for producing steady or oscillating changes of temperature; a portable precision lumeter whose range extends from 0·5 to 10 foot candles, and two experiments showing methods for the measurement of the diameter of very fine quartz fibres. The optical method involved a straightforward application of the laws of diffraction—assuming these laws to hold for fibres of the tenuity employed. In the mechanical method, the twentieth century is content to use ideas furnished by the eighteenth, for the method used is that originally devised by 's Gravesande for the study of the elastic behaviour of wires. The fibre is stretched horizontally between two supports and the sag at the middle due to a mass hung there is measured. The method is used differentially, the *change* in sag due to two different masses m_1 and m_2 being measured. The results obtained by the two methods are in substantial agreement, so long as the diameter of the fibres does not become too closely comparable with the wave-length of the light used in the diffraction experiment.

Microphotography, and the projection of microscopic slides, are by no means new arts. There is, however, room for a micrograph which shall be robust, convenient in handling, reasonably fool proof, and yet a precision tool. Lieut.-Col. J. V. Ramsden's reflex micrograph fulfils these desiderata. The microscope objective is inverted and is illuminated by a lamp and reflector housed in an "upper lamp house" which slides on stout vertical guide

rods. A mirror at the base of the instrument reflects the rays which form the final real image diagonally upwards and outwards, so that the image is projected on to a very conveniently situated reticulated screen, where it may be studied, photographed and discussed at leisure. The instrument affords a very happy combination of precision, simplicity and strength of design, despite the fact that minor improvements can, and almost certainly will, be made in certain of the details.

Mr T. Carlton Sutton exhibited a calorimeter and accessories for measuring, by means of the heat evolved, the energy of detonation of high explosives. The charge is placed in a container which is suspended in a large closed calorimeter. The detonation shatters the container, and the calorimeter, which still contains the fragments of the container is immersed in water, the rise in temperature of which gives a measure of the heat evolved. The calorimeter is constructed on an engineering scale and the charges used may be as much as half-a-pound. The effect on the energy of detonation of factors such as the density of pelletting, size of charge, and the strength of the confining envelope has been studied.

The British Thomson-Houston Company, Limited, gave a demonstration of the audio-frequency characteristics of amplifiers with various forms of coupling. The characteristic curve is traced out by a spot of light moving over a screen, the frequency scale being horizontal, and the output voltage of the amplifier being shown on the vertical scale.

They also exhibited an exceedingly convenient form of analyser for measuring the magnitudes of the separate harmonics in potential or current waves. The potential wave under analysis is connected, through a series condenser, to the moving coil of a dynamometer. Through the fixed coil is passed a sinusoidal analysing current whose frequency is exactly that of the desired harmonic. This picks out the required harmonic in the current in the moving coil. The apparatus is portable and the method seems to be rapid and exact. Harmonics in a potential wave can be found correct to 1/20th of one per cent. of the fundamental, and the magnitude of any single harmonic can be checked in five minutes.

As the writer remarked at the outset, it is impossible in the allotted space and time to give to each exhibit the attention which it merits. Taking the section as a whole, it provided a remarkable and impressive picture of the activity of British research in applied physics, and few of those who studied the exhibits with any care could leave the section without feeling the force of Johnson's remark after examining an important manufactory, "Sir, I have enlarged my ideas."

Not the least pleasant memory of the Exhibition is that of the courtesy and willingness to explain and to assist shown by all of those who took part in the demonstrations.

SCIENTIFIC ELECTRICAL INSTRUMENTS

By E. H. RAYNER, Sc.D., F.Inst.P.

The exhibits of the Cambridge Instrument Co., Ltd., included a scheme of three Duddell Oscillographs suitable for three-phase operation at 75,000 volts between the vibrators. For optical reasons the three units have to be close together, and thick glass plates are used to provide the necessary electrical shields.

Another interesting type of oscillograph is a simple projection pattern, the Cambridge Wave Form Indicator, suitable for central station use (Fig. 1). A synchronous motor provides the usual time traverse of the image; but advantage is taken of persistence of vision to switch on to the vibrator different circuits in turn in rapid succession, so that the current and voltage of a circuit may be delineated for visual observation, giving the

impression obtained normally with two vibrators. There seems to be a distinct future for an extension of this idea, for general research purposes, when dealing with periodic electric quantities, as it enables an instrument with one or two vibrators to indicate the varying values of a number of quantities. The instrument is mounted with a translucent screen in a case suitable for switchboard use, with a metallic filament lamp as the source of light. (See further description of this instrument on p. 59, under "Commercial Indicating Instruments.")

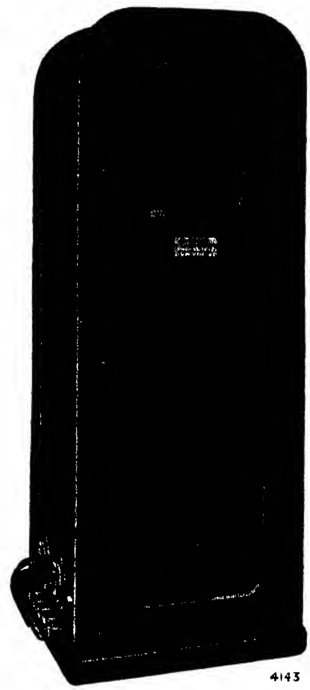


Fig. 1. Cambridge Wave Form Indicator

A Low Tension Schering Bridge (Fig. 2), for the determination of the capacitance and dielectric loss of insulating materials at audio-frequencies, makes use of special screened electrodes. The power factor can be read directly by the indication of a variable condenser arranged in the usual Schering manner. Capacities of 0·060 to 1·0 microfarads and power factors of 0·001 to 0·5 can be dealt with.

An improved design of the Campbell Mutual Inductometer has been evolved, allowing of a considerably better spacing of scale divisions than in earlier models. It has two ranges, 0·2 to 21 or 1·0 to 105 microhenries. The total range is 10,000 for mutal inductance and 20,000 microhenries for self-inductance. The addition of suitable resistances makes the instrument available for the measurement of self-inductance and effective resistance.

The method of causing the moving part of a galvanometer, carrying a delicate thermo-junction, to approach a heating coil and so generate a current and operate a relay, has been adapted to a hair hygrometer in the apparatus for Automatic Humidity Control developed by the Cambridge Company in conjunction with the British Research Association for the Woollen and Worsted Industries. A variation within about 1½ to 70 per cent. humidity is

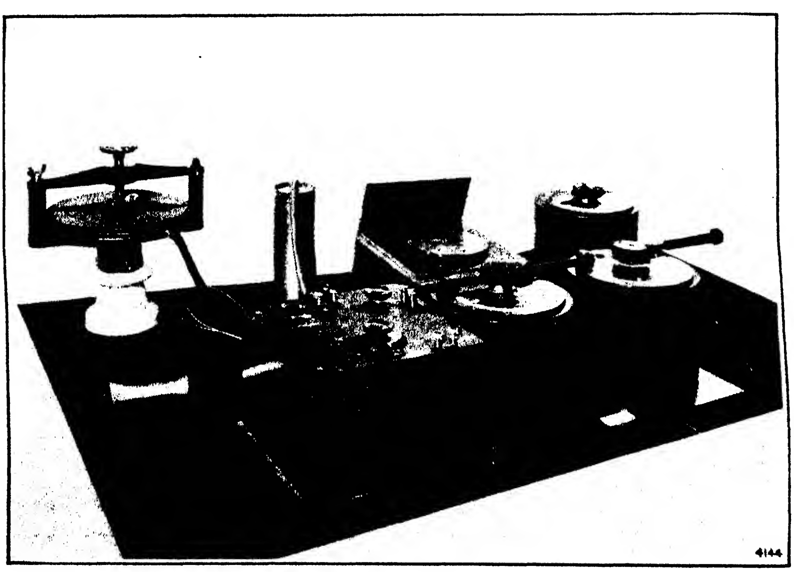


Fig. 2. Low Tension Schering Bridge

mentioned as having been obtained over a period of several weeks. The apparatus has already been described in detail in this *Journal**.

A Temperature Deviation Indicator with a large dial shows whether a temperature differs appreciably from any set temperature. Variations each way up to 25° C. are indicated, and signal lamps of different colours show the direction of deviation at a distance. Platinum resistance thermometers are used. A similar indicator for lower temperatures is made, using a mercury-in-steel thermometer, a range of three colour signals indicating low, correct and high temperature ranges.

Important improvements in sensitivity have been made in Paschen type galvanometers, largely through the development work of Mr A. C. Downing. Where a very sensitive type of galvanometer is required this should be considered. A suitable method of installation is important, as in all cases of instruments of great sensitivity. In one instance disturbance by mechanical vibration has been reduced by a thick pile of brown paper suitably weighted.

A new and simpler form of the well-known Wilson-Shimizu cloud expansion apparatus for observing α, β and X-ray tracks, was shown. The new model has been designed especially as a demonstration apparatus for use in schools and colleges.

Messrs Gambrell Bros., Ltd., exhibited a High Tension Bridge for the comparison of the insulation of a cable or similar plant with that of an air condenser. The instrument makes use of the customary Schering adjustment, in which the power factor is indicated by the value of a continuously variable condenser. The most important item of equipment for this type of measurement is a suitable condenser, and for this purpose a special air condenser has been designed. Such condensers must be capable of being placed in parallel with the cable, so that they must withstand the whole voltage with appreciable power loss. The power factor of such a condenser should not be greater than one or two parts in ten thousand. The condenser shown has been designed for 150 kilovolts.

Messrs Gambrell also showed an Oil Testing Bridge. A multiplate condenser which can be used in a test vessel containing about a gallon of oil is connected to a power loss bridge of the above type. Voltages up to 3000 may be used.

The M.L. Magneto Syndicate, Ltd., exhibited apparatus for the Testing of Permanent Magnets. An interesting equipment for the approximate and rapid measurement of the magnetic characteristics of permanent magnets gives results in c.g.s. units. The adjustments for shape and size of specimens are made by setting resistance dials which are graduated in terms of volume and cross section of the magnet. Tests can be done in half a minute, giving remanence and coercive force and information for plotting the demagnetizing B-H curve.

This firm also showed an extremely ingenious Pneumatically Operated Miners' Electric Lamp (Fig. 3). The lamp is a self-contained unit consisting

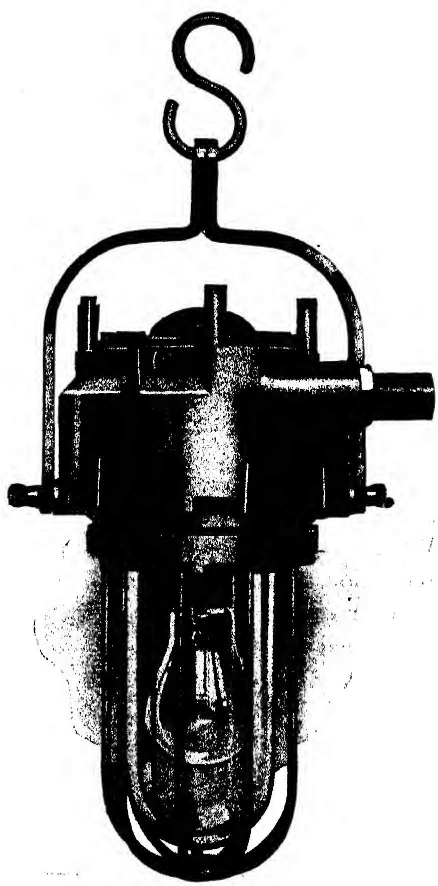


Fig. 3. M.L. Pneumatic Electric Lamp

* *Journ. Scient. Inst.* 4 (1927) 480.

of a compressed air turbine driving an electric generator and supplying current to a metal filament lamp. It has been designed to eliminate fire risk. The generator is an alternator with a revolving field magnet, so that there are no rubbing contacts carrying current and liable to cause sparking; and by means of a spring-loaded valve an exhaust pressure from the turbine is maintained within the generator casing and cover glass of the lamp, which prevents the access of the outer atmosphere while the lamp is burning.

Messrs H. W. Sullivan, Ltd., demonstrated a novel design of Precision Variable Condenser, due to Mr W. H. F. Griffiths, which they have developed for wave-meter purposes. The arrangement is shown diagrammatically in Fig. 4. The terminals are represented by T_1 and T_2, and are connected to the fixed plates only, each of which is guarded by shields at its own potential (S_1, S_2, S_3). The moving plates, MP_1, MP_2, are "floating," not being connected metallically to any part of the circuit. The change in capacity is due to the thickness of the moving plates.

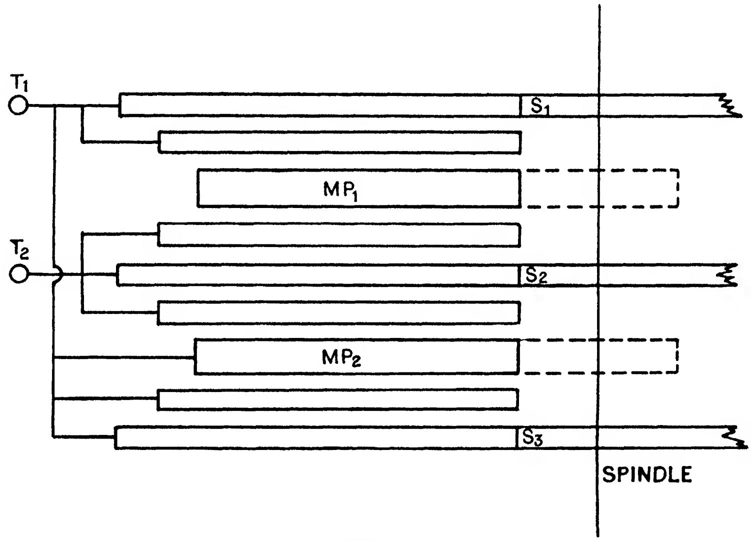


Fig. 4

It will be seen that the arrangement makes the capacity independent of small changes in the axial position of the moving part; and experience has shown that a displacement of 5 per cent. of the total gap produces a change in capacity of no more than 1 part in 10,000. The ratio between maximum and minimum capacitance in a condenser of this design cannot be as large as usual; the value in the instrument constructed being about 2 to 1. When a specially open scale is required it will be seen that this can be obtained by reduction of the thickness of the moving plates.

A Precision Wave-meter for Short Waves, with a range of 10 to 100 metres, has been developed for high accuracy of indication, the capacitance of the resonant circuit being kept large in order to obtain adequate accuracy of indication. A thermionic voltmeter is used to detect resonance. Use is made of steel piano wire for making some of the connexions, where constancy of form is necessary. These are copper plated to reduce their effective resistance.

A number of other interesting items shown by Messrs Sullivan, such as wave-meters, and fixed and variable condensers for different grades of accuracy, are indications of the essential importance of high accuracy in fixing and measuring wave-lengths of modern radio transmission. An equipment for dielectric loss measurement at audio-frequencies, using a telephone as detector, is made for testing paper, cloth and other insulating materials.

Capacitances of the order of 0·1 to 1·0 microfarads are suitable, and the power factor is determined from the values of a variable condenser according to the usual Schering balance arrangement.

Among a fine selection of high class laboratory instruments shown by MESSRS H. TINSLEY & Co., including various types of potentiometer, resistance bridges, air condensers for wave-meters and other high frequency measurements, the items of novelty included a new type of double sliding contact designed to be satisfactory in operation when mounted on uneven ebonite or other material. A constant contact resistance of the order of 20 microhms is claimed. A quick tuning vibration galvanometer has the adjustment for tuning so arranged as to show the frequency on a calibrated dial, so that adjustment for frequency can be made with certainty, instead of by trial and error, as is often the case.

MESSRS ELLIOTT, BROS. (LONDON), LTD., have developed a useful series of thermojunction current detectors in vacuo. For many purposes the thermojunction circuit must be separate from the circuit in which the current is to be measured, so as to avoid the effects of capacity currents. This is usually done by arranging them close together in a glass vessel in vacuo. The efficiency of heaters with actual contact is generally considerably higher, and in the design of some exhibited the heating circuit is in the form of spiralled wire wrapped round the thermojunction, but insulated from it by a thin glass sleeve fused on to the junction. The largest dimension of the system is about 2 mm. It can be obtained mounted with a four-point contact fitting into one of the Western Electric small valve holders.

MESSRS W. EDWARDS & CO. demonstrated an interesting collection of modern vacuum pumps and apparatus, including the "Megavac" pump, the latest development of the well-known "Hyvac" type, but of increased capacity, up to 57 litres per minute. Messrs Edwards showed a new and inexpensive form of Direct Reading Vacuum Gauge, a modification of the Pirani type, in which a wire heated by current from a dry battery is sealed into a glass tube connected to the vacuum system. Attached to this wire is a thermojunction, with leads to an indicating dial upon which a sensitive record of the fluctuations of pressure is obtained.

COMMERCIAL INDICATING INSTRUMENTS.

BY A. C. JOLLEY, F.INST.P.

A VERY excellent and representative collection of commercial indicating instruments was shown, and it was interesting to note that the high standard of design and manufacture which has been so marked during recent years has not only been maintained but in many cases surpassed. Interior finish was never better than in many of the examples, which were freely displayed; while in many instances progressive stages in manufacturing processes, as well as component parts of the structure, were shown. Thus considerably greater interest was stimulated than can ever be obtained from a monotonous display of polished and decorated cases, which might or might not contain a working movement.

Among the most notable developments in this section as a whole, were the extended use of cobalt chrome steel and also Mumetal in instrument construction; the employment of the thermojunction for the measurement of direct and alternating currents up to radio frequencies, and the development of the induction pattern ammeter as an instrument of precision.

The oscillograph has now become a very important adjunct in connection with practically every branch of the electrical industry, but one would hardly expect that such an instrument could be converted into what is practically a switchboard indicating instrument with a case

but very little larger than the average recording instrument. Nevertheless the CAMBRIDGE INSTRUMENT CO., LTD., have solved the problem in a very neat and ingenious fashion, and were showing such an instrument in operation, delineating current and voltage wave forms simultaneously on a translucent window in the case of the instrument.

In this Cambridge Wave Form Indicator* a beam of light from a metal filament lamp is focussed on to a mirror attached to a coil. The coil is held in the gap of a permanent magnet by stretched suspensions, so adjusted that the coil vibrates in mechanical resonance with the frequency of the current passing through it. The natural period of this coil is about 0·001 second. The reflected beam is focussed on to a system of mirrors, which is rotated by means of a small synchronous motor driven from, or synchronously with, the source of supply. The vibrating beam is thus drawn out in the time axis at right angles to the original deflection, which is proportional to the instantaneous current passing through the coil; the reflected beam therefore appears as an apparently stationary wave form trace on the translucent screen.

To enable voltage and current wave forms to be traced simultaneously, a commutator attached to the shaft of the rotating mirrors connects the vibrating coil alternately (1) in series with a non-inductive resistance across the mains, the value of this resistance being such that the current passing through the coil is a little less than 0·1 ampere, and (2) across a shunt, which is fed from the secondary of a suitable current transformer. As the wave forms are taken from the same circuit they appear on the screen in their proper phase relation.

Another excellent instrument shown by the same Company is the Cambridge Recording Potentiometer, designed for the accurate measurement of small differences of potential. It is of the slide wire type, the wire contact being automatically adjusted to the position of balance by the recorder mechanism. The galvanometer, which is connected in series with the E.M.F. to be measured, is a relay which, on being deflected, moves the slide wire contact, through a mechanism, in such a direction as to tend to restore balance; so that the position of the contact is a measure of the E.M.F. The galvanometer is of the moving coil type, and has a long pointer with a cylindrical tip (Fig. 1, *a*), which swings horizontally above a metal jaw (*b*) which is raised periodically. Just above the pointer tip are the horizontal members (c, c_1) of two bell crank levers, which are pivoted on the frame casting (d and d_1).

When the circuit is out of balance the needle (*a*) is clamped by the lower jaw (*b*) against one of the horizontal members, under which it happens to be, so causing the corresponding lever to tilt. The motion of the lever operates a clutch mechanism (g or g_1), which results ultimately in the movement of the contact in one or other direction, depending on which lever is tilted, round a circular slide wire; and in the corresponding movement of a pulley carrying a cord to which the carriage of the recording pen is attached. This carriage moves on horizontal rods, under which the chart is driven by clockwork at a speed which may be varied from ¼ to 2 inches per hour.

The power required to raise the lower jaw (*b*) and to wind the clock for the recorder chart is obtained from a hot-wire motor mounted in the back of the recorder case (see *M* in Fig. 1 on p. 63). The hot wire is wound on a series of upper and lower pulleys, the upper ones being carried on a frame fixed to the recorder case, while the lower pulley frame is free to move, and carries a vertical push rod, shown at (*b*) in Fig. 2. This rod bears against one end of a horizontal lever (*c*), the other end of which forms the lower jaw of the galvanometer relay mechanism. A spring maintains the lever in contact with the vertical push rod, and keeps the hot wire taut. The lever also actuates, through a vertical link mechanism (*l*), a tilting mercury switch (*h*) and a spring-controlled rachet mechanism (*i*) which winds the clock for the recorder chart.

* See Fig. 1 on p. 55.

When a current passes through the hot wire it expands, causing the push rod to move downwards, and the consequent movement of the horizontal lever raises the lower jaw against the galvanometer pointer and at the same time causes the mercury switch to tilt,

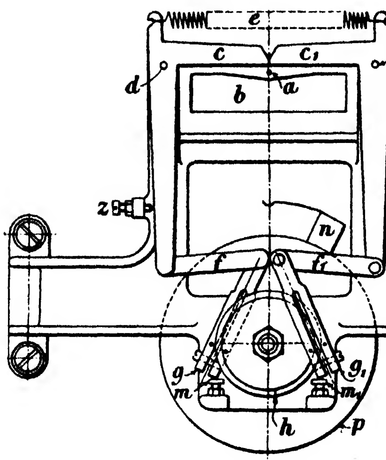


Fig. 1

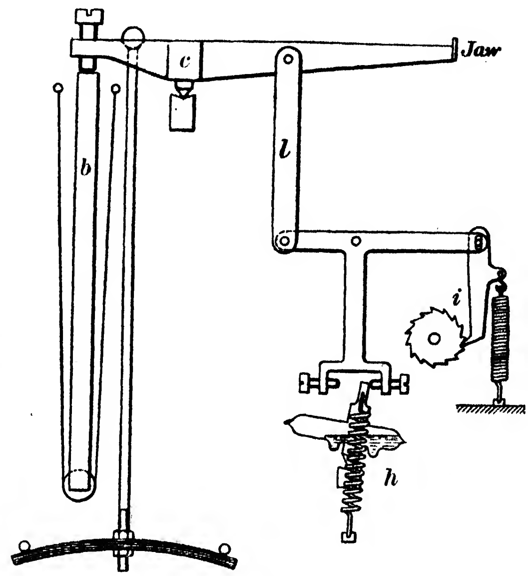


Fig. 2

thus breaking the circuit. The hot wires then cool and the lever returns to its original position, restoring the circuit and commencing the cycle of operations once more. These operations normally occur eight times per minute, so that wear and tear are reduced to a minimum and lubrication is unnecessary.

MESSRS ELLIOTT, BROS. (LONDON), LTD., exhibited their new thermal instruments, which incorporate a new type of thermo-couple in which the heater is insulated from the couple itself. In most of the former instruments of this type, to secure a sensitivity suitable for a commercial instrument, the junction has been put into metallic contact with the heater. (The Duddell thermo-ammeter is, however, an exception.) As a consequence considerable trouble arises with such instruments when designed for small current ranges, because of the unsteady zero and the large reversal error which occurs when D.C. is employed to calibrate them. Both these troubles are eliminated in the Elliott instrument by employing independent couples which, for currents ranging from 5 milli-amperes to 1 ampere, are mounted with their heaters in highly evacuated bulbs, a number of which were exhibited.

An interesting instrument on this principle was shown in the form of a voltmeter for a range up to 1·5 volts, with a sensitivity of 100 ohms per volt and suitable for all frequencies up to and including radio frequency. The instrument was designed for work in connection with track signalling, but has of course a wide range of useful applications.

MESSRS CROMPTON AND PARKINSON, LTD., exhibited a portable A.C. multirange ammeter and multirange voltmeter, a development of the ring type of instrument which they have shown previously. In the instrument exhibited 100 ampere turns are required through the magnetic circuit to produce full scale deflection, and to facilitate the inclusion of the instrument in the circuit, the magnetic circuit has a detachable part projecting outside the wooden case. If this is removed the conductor can easily be inserted, and the magnetic circuit again completed about it without in any way interrupting the electrical circuit; or a

larger number of turns, in the form of a separate coil, may be employed for small current ranges.

By using a fine wire coil and extra resistances the instrument is converted into a voltmeter, the volt range being built up by screwing together standard series resistance units, in the convenient manner which has been developed by this firm. B.S. first grade accuracy is obtained with the instrument as an ammeter on frequencies from 25 to 100 cycles, and as a voltmeter on 25 to 60 cycles, but on higher frequencies the voltmeter requires special calibration.

MESSRS EVERETT EDGCUMBE & CO., LTD., were showing the new Everett Edgcumbe-Warren Master Frequency meter. By means of this instrument the frequency of a power station can be kept almost perfectly constant; in fact, expressed in terms of time, the frequency can readily be maintained within $\frac{1}{4}$ minute per day (corresponding to an accuracy greater than $\frac{1}{60}$th of 1 per cent.). This is accomplished by means of an accurate clock, combined with a Warren synchronous motor; two hands, one driven by each motor, being mounted concentrically so as to move over a single dial, or alternatively so arranged that

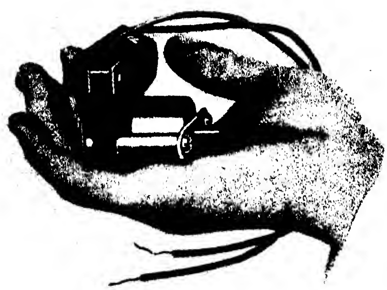


Fig. 3

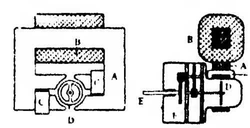


Fig. 4

the clock and the motor act differentially upon a single hand. In either case, the hands serve to show the attendant at a glance whether the station frequency is correct or is above or below the normal.

Fig. 3 gives some idea of the compactness of the Warren motor and Fig. 4 its simple construction. A rotating field is produced by the shading rings *C*, *C*, and the annular rotor *D* is drawn round by hysteresis, the effect of eddy currents being quite negligible. As a result the speed of the rotor is absolutely synchronous, irrespective of the load; the power consumption is only 3 watts and the gearing is such that the spindle *E* makes 1 revolution per minute or 1 revolution per second as may be desired.

A new form of Directional Current Relay was also shown. Messrs Everett, Edgcumbe were the first to emphasize the importance of compensating such relays against the fall of voltage which is inevitable under severe fault conditions, and more than fifteen years ago they introduced a "reverse current" relay which operated at a current which was, within wide limits, independent of voltage, as distinct from the usual reverse power relay in which the current necessary to cause operation increased in proportion as the voltage fell. The importance of this condition is now fully recognized, and other compensated relays have been put upon the market. They are, however, mostly of the induction pattern, which is far less efficient than the "ironclad dynamometer" principle which has been adopted by Messrs Everett, Edgcumbe in their latest pattern of directional current relay.

Fig. 5 shows one of these instruments provided with a definite time lag device.

A new pattern of Induction Ammeter and Voltmeter was also shown. Messrs Everett, Edgcumbe have devoted much attention to improving this type of instrument which has the advantage of a scale subtending an angle of 300°. Hitherto such instruments have been subject to very grave temperature and frequency errors. In the new design exhibited

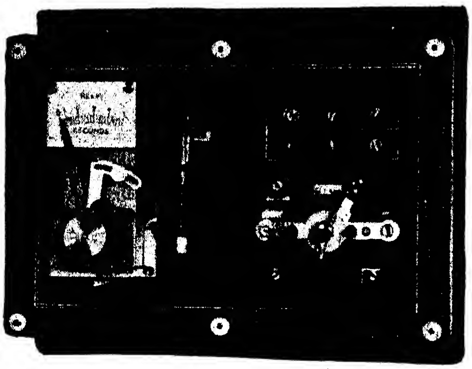


Fig. 5

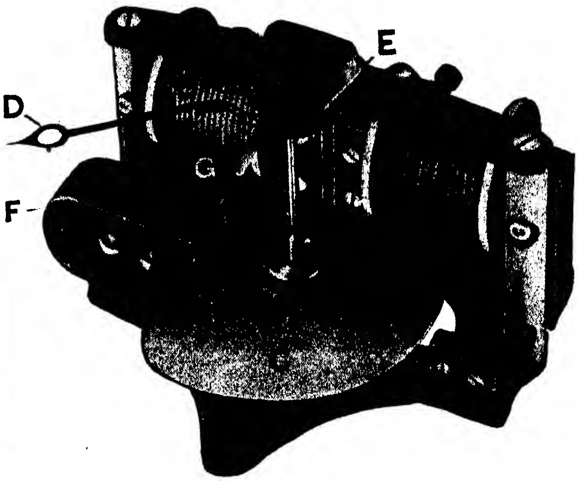


Fig. 6

(Fig. 6), the usual shading ring is dispensed with, and the necessary phase displacement obtained by a second electromagnet, the current in the winding of which is made to lag about 45°, by shunting the coil with a non-inductive resistance. By properly proportioning the inductance and temperature coefficients of the various elements it has been possible to produce an instrument which complies with the first grade requirements of B.S.S. 89.

Messrs Evershed and Vignoles, Ltd., showed a fine range of their "Megger" and "Bridge Megger" resistance measuring instruments, and the MEG. insulation tester, together with the "Ducter" low resistance testing set and "Megger" earth tester. The Midworth Distant Repeater has been considerably developed since the last exhibition, and a manually operated transmitter, controlling distant indicators, and a power-driven 20-inch dial receiver was shown in operation.

An exhibit of The Foster Instrument Company was a case containing the component parts of their well-known "Resilia" moving coil instruments, and it was very interesting to note that the firm are employing cast cobalt steel magnets for some of these instruments and that the magnets are given an effective protection and handsome finish by coating with a hard white enamel. A new M-class pyrometer, consisting of a simple robust thermo-couple and small metal-cased indicator, for use where space is very limited, was also shown.

Messrs Nalder, Bros. and Thompson, Ltd., have also devoted particular attention to the induction pattern instrument, and have produced an instrument with an inherent accuracy higher than that required by the first grade B.S.S. The temperature coefficient of the instrument is less than 0·02 per cent. per 1° C. and the frequency error less than 0·2 per cent. for a 10 per cent. rise or fall of frequency. Power Factor Meters, Deflectional Frequency Meters and Rotary Synchroscopes, of the well-known Nalder, Bros. and Thompson and Lipman patents, were also exhibited, together with their new portable dynamometer instruments of precision accuracy. A range of overload, discriminating, and other relays

was also shown, among which a new reverse current relay for alternating current, which operates practically independently of the voltage of the controlled circuit and requires only a very small V.A. consumption on the current coil, was noted.

THE RECORD ELECTRICAL CO., LTD., exhibited their "Cirscale" instruments, of the moving iron and moving coil types, in a large range of patterns, together with the change coil testing set, suitable for testing on A.C. and D.C. for voltages up to 750 volts and currents from 1 to 600 amperes. They also showed a series of educational and demonstration models. The whole movement is clearly visible in a glass case, and the transparent celluloid dials permit of the instrument being observed from either front or back, or it may be placed in the path of a beam of light and projected on to a screen.

THE STONEBRIDGE ELECTRICAL CO., LTD., showed examples of their electrostatic voltmeters, which, up to 15,000 volts A.C., can be made with internal series condensers. A new range of ferro-dynamic recorders, of small overall size and weight and yet retaining all the main features of the larger type of instrument, were exhibited. An interesting feature of this firm's recorders is the incorporation of the chart-driving clock, and the chart itself, in a single removable unit.

At the exhibit of the WESTON ELECTRICAL INSTRUMENT CO., LTD., was shown a new direct reading thermionic valve tester, consisting of a number of the company's well-known indicating instruments, conveniently assembled in a case, and provided with the necessary internal wiring and switches so as to show the voltage amplification factor, the plate impedance in ohms, the mutual conductance in micromhos and the plate current.

TEMPERATURE MEASURING APPLIANCES

BY EZER GRIFFITHS, D.Sc., F.R.S.

THE exhibits of the CAMBRIDGE INSTRUMENT CO., LTD., included a recording potentiometer combining the mechanism used in the thread recorder and the recording mechanism of the Callendar recorder. It can be used for a variety of purposes, such as temperature recording or regulation by thermojunctions. An ingenious hot wire motor (shown at *M* in Fig. 1) operates the mechanical parts, including the winding of the clock. The expansion of the wire by an electric current operates a small mercury tilting switch which cuts the current off. The work available in the subsequent cooling winds the clock. This is repeated about eight times a minute, and the clock spring has enough energy stored in it for several hours' operation if the winding gear fails. (See detailed description of this instrument on p. 59, under "Commercial Indicating Instruments.")

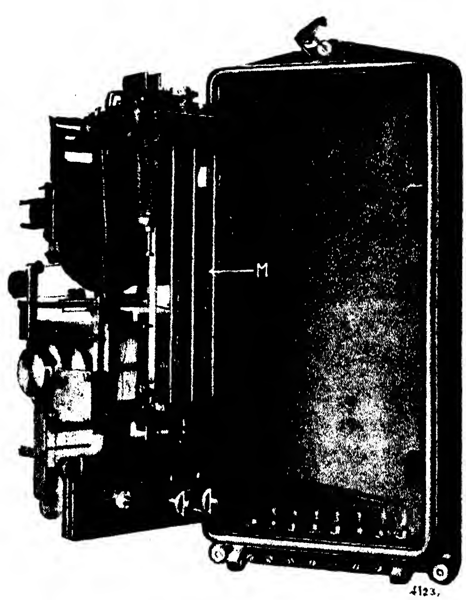


Fig. 1. Recording Potentiometer

Other exhibits of the same firm use various types of surface pyrometers for taking the temperature of heated surfaces under working conditions. The majority of these utilize one or more thermocouples consisting of a thin strip of two metals with the junction at the mid-point, this

strip being held taut by a spring bow. The ends of the strip are connected to a millivoltmeter which is either mounted on the same framework as the thermocouple or forms a separate unit which is connected to the thermocouple by a length of leads.

A surface pyrometer of the Prong type, however (Fig. 2), does not utilize a strip thermocouple, but the two elements are left open-circuited at the hot junction end; the two ends are pointed and one is left straight and stiff while the other is coiled, and consequently

Fig. 2. Prong Type Surface Pyrometer

springy. When the thermocouple is pressed on a metallic body, which is a good conductor, the body itself forms the hot junction. The provision of one springy and one solid point ensures good contact being made with the hot surface when the thermocouple is pressed on it at any reasonable angle.

The instrument gives quick and reliable results provided the surface is moderately clean and a good conductor of electricity, for example, copper, brass, gun-metal, phosphor-bronze, duralumin, aluminium, etc. A satisfactory reading cannot be obtained on iron or steel surfaces. The range is from 200° C. up to say 1000° or 1200° C.

THE FOSTER INSTRUMENT CO. showed a total radiation pyrometer fitted with removable and cleanable window at the centre of the receiving tube, to protect the sensitive couple from damage by dust or fumes.

WIRELESS APPARATUS. By R. L. SMITH-ROSE, D.Sc., Ph.D., A.M.I.E.E.

THE wireless apparatus exhibited this year was notable for its considerable variety, ranging from an elaborate commercial receiver to the simpler broadcasting set, and from massive standard variable condensers of precision to the smaller type nowadays in the possession of everybody. With one or two exceptions the progress made since last year's exhibition appears to lie in details of design and construction rather than in any radical departure from previous ideas and practice. In such a *Journal* as this it is perhaps fitting to deal first with apparatus relevant to the scientists' laboratory, and to give second place to that apparatus which is of more domestic utility.

LABORATORY APPARATUS

Most prominent among the exhibition of laboratory wireless apparatus was the stand of MESSRS H. W. SULLIVAN, LTD. This firm showed a large range of precision variable condensers and wave-meters, and a variety of apparatus used for alternating current measurements at both audio- and radio-frequencies. A notable departure from previous designs was found in the "Sullivan-Griffiths" precision variable air condenser, in which a number of self-screened elements are built up with the dielectric air gaps on either side of each of the moving plates, which are insulated from each other and from the condenser terminals. The inter-capacity between adjacent moving plates is rendered negligible, so that any axial displacement of the moving system is of no consequence. This novel design is claimed to overcome inaccuracies due to age and to compensate for any irregularity of movement other than that of true rotation about the axis. Such a condenser should prove useful

where high accuracy and permanence of calibration are required, and it is particularly suitable for use with sub-standard precision wave-meters. Standard variable condensers of the normal pattern, either alone or as parts of wave-meters, were exhibited also by Messrs H. Tinsley & Co. and the Dubilier Condenser Co. (1925), Ltd. To meet the demand for accurate measurements of frequencies corresponding to wave-lengths of from 10 to 100 metres, Messrs Sullivan have produced a sub-standard wave-meter for this range in which the minimum capacity used at any portion of the scale is 250 micro-micro-farads.

While on the subject of condensers the wide range of exhibits of the Dubilier Company must be mentioned. This firm appears to provide every class of condenser imaginable, from the small fixed or variable condensers used in broadcasting receivers to the high-voltage radio-frequency type required in high-power wireless transmitters. The application of condensers to wave-meters, high-tension supply units, gramophone pick-up devices, and means for the suppression of interference in wireless receivers from small electric motors, was well illustrated in the exhibits on this stand. A novelty also to be found here was a toroidal type of high-frequency transformer, which reduces the stray field between the stages of an amplifier and its consequent troubles.

In the sphere of electrical measurements, several firms showed models of direct-current ammeters and voltmeters, which have been specially designed for use with wireless receivers. Some useful vacuum thermo-couple units for the measurement of small radio-frequency currents were exhibited by Messrs Everett, Edgcumbe & Co., Ltd.; while Mr E. B. Moullin showed some interesting modifications of his well-known thermionic voltmeter, one of which is now available for the measurement of peak and mean values of alternating potential up to 500 volts.

COMMERCIAL APPARATUS

Among the more commercial wireless apparatus was the auto-alarm device of the Radio Communication Co., Ltd., used for the purpose of registering a distress call and giving an alarm on board ship, without the necessity for maintaining a continuous operator watch. To meet the demand for a reliable instrument for the interception of daily press messages in almost any part of the world, Marconi's Wireless Telegraph Co., Ltd., have produced an efficient, selective receiver, which, in three models, covers a wave-length range of from 1600 to 25,000 metres. The growing importance of short-wave communication is also provided for in the short-wave receiver shown by this company, covering a range of wave-lengths of from 15 to 150 metres. In this receiver the self-oscillating detector valve is separated from the aerial by a coupling valve, in order to eliminate the difficulty of maintaining constancy of signal intensity or of the beat-note frequency due to variations of the aerial or its circuit. A set of components for constructing a somewhat similar type of receiver for the same range of wave-lengths was exhibited by the Igranic Electric Co., Ltd. Another new instrument in this section of the Exhibition was the Marconi Time Signal Receiver, which is used with a frame aerial and is designed for portability, expressly for the use of survey parties for the reception of time-signals from high-power long-wave stations. This instrument should also prove valuable to observatories for the recording of wireless time-signals.

VALVES

That backbone of the wireless industry, the thermionic valve, was shown in all its modern variety as applied to both transmission and reception, on the stands of the M. O. Valve Co., Ltd., the Mullard Radio Valve Co., Ltd., and the Edison Swan Electric Co., Ltd. The collections included the latest types of screened valves, indirectly-heated-cathode valves, and super-power valves for receiving purposes; while among the trans-

mitting valves were to be found those of the high-power silica and metallic-envelope types, with some special modifications for use on short wave-lengths. While admiring the research and development which has resulted in the modern receiving valve with its steady reduction in filament current and increase in output performance, one is sometimes tempted to ask whether such a variety of types as now exists is really necessary. It is possibly a reflection on the psychology of the general public to conclude that a constant change is necessary in order to maintain the sales figures.

GENERAL

A considerable variety of general components for use in wireless receivers was exhibited by several firms, and a prominent feature of these was the display of units for obtaining high-tension supply to valve receivers from the electric light mains, whether alternating or direct current. Several useful types were shown by the Dubilier Condenser Co. (1925), Ltd., Messrs Gambrell Bros., Ltd., the Igranic Electric Co., Ltd., the Marconiphone Co., Ltd., and the Mullard Wireless Service Co., Ltd.

This review may be aptly concluded with the observation that the physicist owes a debt of gratitude to modern wireless developments for supplying a wide range of apparatus useful in his work. Apart from domestic requirements, condensers, inductances and valves are now the everyday tools of many physicists, and mass production has rendered them available at a low price. To quote a final example, who does not remember the mess and bother formerly associated with the attainment of a potential of a few hundred volts for charging a condenser or the needle of a quadrant electrometer? Yet, nowadays, a large variety of high-tension accumulators, similar to that displayed by the Fuller Accumulator Co. (1926), Ltd., is available in a cheap, convenient and easily-maintained form.

OPTICAL INSTRUMENTS. By W. B. COUTTS, M.A., B.Sc., F.R.S.E.

PHOTOGRAPHIC APPARATUS

As in other years, there was an excellent display of photographic apparatus of various kinds. Messrs R. & J. Beck, Ltd., Ross, Ltd., W. Watson & Sons, Ltd., J. H. Dallmeyer, Ltd., and Wray (Optical Works), Ltd., exhibited very complete ranges of their well-known photographic lenses. Apparatus shown for the first time included the Ross Xpres f/2·9 lens, the latest addition to the Xpres series of Messrs Ross, fitted to a Newman and Guardia Folding Reflex camera. Messrs Dallmeyer exhibited the Devry automatic cine camera.

On Messrs Ross' stand was shown the "N.S." Auto Kine camera made by Messrs James A. Sinclair & Co., Ltd.

The principal features of this camera are the double spring driving mechanism, and the care and attention which has been devoted to details with a view to meeting all possible requirements of the user. It is constructed entirely of metal, duralumin being used for the body, and is thus suitable for use in any climate. It holds 200 feet of standard film and can be reloaded in a few seconds. After exposure the film is automatically rewound in the same box. The mechanism is silent both in action and during winding, and 150 feet of film can be driven with one wind. The speed can be varied by means of a simple lever setting device, but it is claimed that once the speed is set, the alteration in the rate of driving from start to finish will not exceed 2 per cent. The finder is of a new type which permits of the operator seeing at one time, a full-size erect view of the picture he is taking, the number of feet of film exposed, and the state of level of the instrument. It is fitted with a Ross f/3·5 Xpres lens.

TELESCOPES AND BINOCULARS

Telescopes suitable for almost every purpose, ranging from vest pocket telescopes to astronomical telescopes on Equatorial mountings, were exhibited by MESSRS ROSS, LTD., W. WATSON & SONS, LTD., and W. OTTWAY & CO., LTD. Messrs Ross exhibited the latest pattern of their now well-known "Dominion" telescope. The instrument shown was fitted with a 4-inch Ross apochromatic objective, and interchangeable eye-pieces giving magnifications of 60 to 180 diameters. Important features of the instrument are its lightness, and the lightness and rigidity of its stand, the telescope weighing 11 lbs. and the stand 20 lbs. It has been designed for use on sheep stations, cattle ranches, etc. where a high power telescope which is both rigid and light is required.

Binoculars were exhibited by MESSRS HENRY HUGHES & SONS, LTD., ROSS, LTD., W. WATSON & SONS, LTD., and WRAY (OPTICAL WORKS), LTD. Of special interest were Messrs Ross' extra wide field prism binoculars, which are made to give magnifications of 6, 7, 9 and 12 diameters, with "real fields" of view of 11°, 9·4°, 8° and 5° respectively; and Messrs Watson's light weight prismatic binocular of magnification 6 diameters, which weighs 11 ozs., as compared with the normal weight of 20 ozs. for this class of instrument.

MICROSCOPES

The principal exhibitors were MESSRS C. BAKER, R. & J. BECK, LTD., JAMES SWIFT & SONS, LTD., W. WATSON & SONS, LTD., OGILVY & CO., and CARL ZEISS (LONDON), LTD. Among the new instruments exhibited are several to which attention might be directed. Messrs Swift's Minim pocket microscope is a highly developed instrument, equipped to take standard objectives and eye-pieces, and all types of illuminating apparatus. It can also be equipped for petrological work. As its name implies it is small and portable, and specially suitable for use by prospectors for oil and minerals. The same firm exhibited a new petrological microscope which is constructed to incorporate both the Dick principles and the rotating stage. New dissecting microscopes were represented by Messrs Swift's "Kew" dissecting microscope for advanced work and Messrs Baker's Boxform dissecting microscope. Messrs C. Baker also exhibited an ultra-microscopic illuminator of new design for the examination of liquids and gases. Messrs R. & J. Beck, Ltd., exhibited a new model metallurgical microscope. This instrument gives a large traverse, and is fitted with a built-in mechanical stage with levelling table.

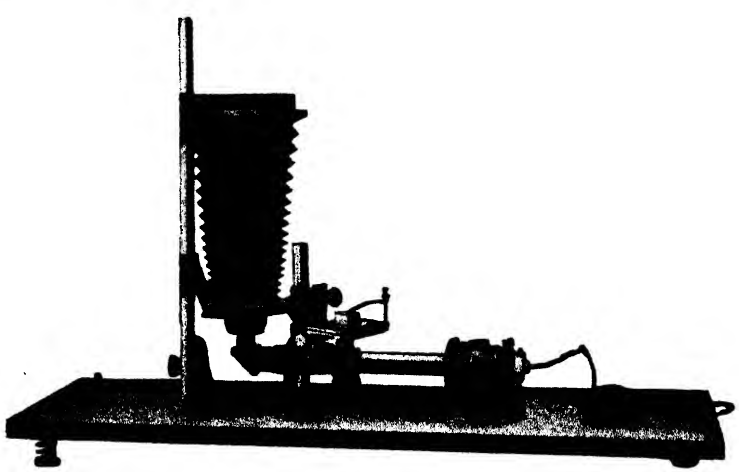


Fig. 1. Leitz Metallurgical Microscope and Camera

Messrs Ogilvy exhibited a selection of the latest Leitz microscopes including a new stereoscopic binocular microscope of modified Greenough type. They also exhibited a new Leitz metallurgical microscope and camera for the workshop (Fig. 1). This is a compact and inexpensive form of apparatus for commercial use. It can be used both for visual observation and photography. The camera and microscope can be used independently for the photography and examination of large specimens.

Messrs Zeiss exhibited a new Winkel-Zeiss students' stand G, and their new research microscope stand F, a large stand with interchangeable tubes, which may be used either for monocular observation, or for binocular and stereoscopic observation with a single objective. In this instrument particular attention has been paid to stability. The same firm also exhibited their Cardioid condenser with azimuth diaphragm fitted to a large stand G, and the Péterfi micro manipulator, by means of which microscopically small bodies can be subjected to experimental investigation in the field of view of the microscope.

PROJECTION APPARATUS

The number of exhibits in this class compared favourably with that in recent exhibitions, and although comparatively few new instruments were shown, many improved models were on exhibition. It is apparent that an ever growing interest is being taken in the design of optical projection apparatus by users and manufacturers. Many of the improvements embodied in the instruments shown this year are designed to meet the demands of users, either with a view to increasing the scope of the instrument or of simplifying its manipulation.

Projection Lanterns. Messrs Newton & Co. were the principal exhibitors of this class of apparatus. Among instruments exhibited for the first time might be mentioned the new inexpensive model demonstrator's lantern. This instrument closely follows the design of this firm's standard model demonstrator's lantern, which was also exhibited. It is provided with open horizontal and vertical stages, and can be used in conjunction with the projection microscope, but is not provided with any attachment for opaque projection. Messrs Houghton-Butcher (Great Britain), Ltd., showed some new models of their well-known "Optiscope" series of lantern slide projectors. The Optiscope No. 10 has been designed to give a range, of from 25 to 75 feet, combined with sharp definition and ample illumination. An Aldis Butcher projection lens is fitted, and the illuminant is a 500 watt concentrated filament, mirror backed projection lamp. The lantern, lamp, and up to 100 slides are carried in a metal case. The outfit is therefore very portable and convenient for travelling. A noteworthy feature is the accessibility of the condenser lenses for cleaning.

Epidiascopes. Instruments for opaque projection were more numerous than other types of projection apparatus, and once more formed one of the most popular features of the Exhibition. Several new instruments were shown, and in many cases earlier models had been improved.

Messrs C. Baker demonstrated a new instrument for opaque projection only, called the Metron Episcope. This instrument is fitted with an f/3·5 anastigmat lens and illuminated by two 500 watt gas-filled lamps. It projects a picture 8 feet square on a screen at a distance of 18 feet. The instrument was designed to give the extra illumination asked for by some users, and also for use in partially darkened rooms. A large size page or sheet can be projected, and the platform is designed to accommodate thick books or other objects. One noteworthy feature is the well-ventilated body, which is quite cool even after a lengthy run.

Apparatus for both opaque and lantern slide projection was exhibited by Messrs Garner & Peeling, Ltd. (Zeiss Ikon epidiascopes), Newton & Co., and Carl Zeiss (London),

LTD. The Newton Epidiascope was exhibited for the first time. In appearance this instrument follows the lines of the projection lantern, and is fitted with the usual high grade objective and slide carrier front for slide projection. The projection lens and mirror for opaque projection are carried on top of the body, the lens being an anastigmat, in a lever and screw focussing mount. A useful feature of the instrument is that change from opaque to lantern slide projection or vice versa can be made without movement of either lamp or optical parts (Fig. 2).

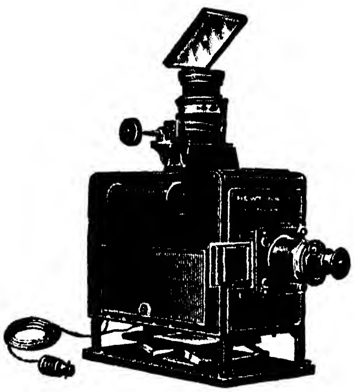


Fig. 2. The Newton Epidiascope

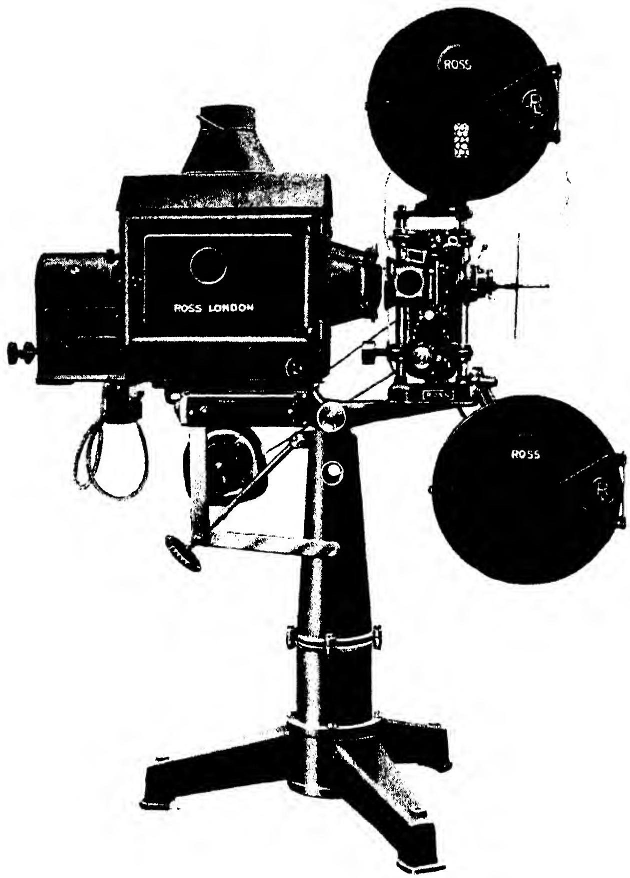


Fig. 3. D.C. Model Ross Projector

Kinematograph Projectors. These were well represented. MESSRS ROSS, LTD., exhibited the D.C. model Ross projector which is an entirely new pattern projector for kinema theatres. This instrument possesses many noteworthy features, fulfils the most stringent requirements of the fire regulations, and is of elegant appearance. It is fitted with a Ross high intensity searchlight arc lamp, with a 10-inch ellipsoidal mirror, and a Ross f/2·4 D.P.L. projection lens. A fine focussing adjustment is provided. The gears are of improved design, silent in operation. Racking can be carried out without alteration in the lengths of the film loop. The gate can be removed for cleaning, and the stand, which is of new design, is readily adjustable to any height by the use of interchangeable extension pieces (Fig. 3).

Educational projectors fitted with Aldis Butcher projection lenses were exhibited by MESSRS HOUGHTON-BUTCHER (GREAT BRITAIN), LTD., who displayed films illustrating the life-history of plants and insects speeded up 20,000 times, by means of one of their No. 5 Empire projectors. This must have been a most interesting object lesson in the educational

value of the kinema to the many visitors who witnessed these demonstrations. The same firm showed a new lantern slide attachment fitted to their projectors, and a new, No. 9, Empire model projector which had been introduced with a view to providing a projector taking standard film, at moderate price, for use in the home or schoolroom, under conditions where the special provisions of the Cinematograph Act do not apply. MESSRS GARNER & PEELING, LTD., exhibited the Ica Monopol educational and home projector, and MESSRS J. H. DALLMEYER, LTD., showed two instruments, the All-British Ruby cine camera, which employs 16 mm. film and the De Vry automatic cine projector, which is a portable instrument of American manufacture, employing standard film. Both these instruments are provided with Dallmeyer optical equipment.

Special Appliances. New instruments which might be mentioned include the Leitz profile projection apparatus exhibited by MESSRS OGILVY & CO., a vertical apparatus for projecting the profiles of screw threads and other small mechanical parts which require testing for extreme accuracy. Magnifications of 10, 25, and 50 are used. The source of illumination is a metal filament lamp. The instrument is a large workshop instrument, and its main advantage would appear to be that, in comparison with the ordinary horizontal method of projection, no dark room is necessary and valuable floor space is saved.

An interesting device called the Moscon Macrograph was exhibited by the LONDON INSTRUMENT CO., LTD. This device was designed for the British Mosquito Control Institute, Hayling Island, and is a simple portable apparatus for the direct projection on a translucent horizontal screen of an enlarged image of any object under the microscope. The microscope can be placed on the floor and the macrograph attached to any convenient table or shelf. The enlarged image can be demonstrated to several students at once or can be traced or photographed. The dark slide provided is of unusual design, adjustable to any size of plate up to half plate, and with a special form of hinged shutter. This form of dark slide might conceivably be adapted to other instruments with advantage.

REFRACTOMETERS

MESSRS BELLINGHAM & STANLEY, LTD., exhibited their new model refractometer, in which special attention has been paid to stability and convenience in use (Fig. 4). It is provided with a sheet metal cover secured to the upright by means of a single screw, and provided with a leather handle. MESSRS ADAM HILGER, LTD., exhibited a new ultra-violet refractometer.

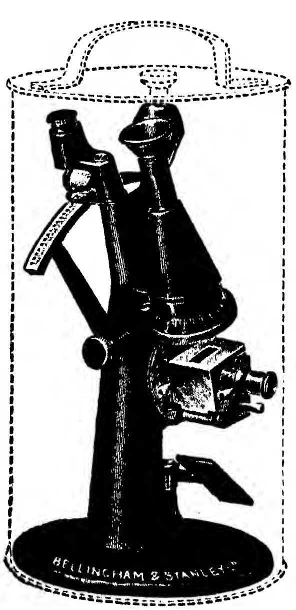


Fig. 4. New Model B-S Refractometer

SPECTROSCOPIC APPARATUS

This was well represented, the principal exhibitors being MESSRS R. & J. BECK, LTD., BELLINGHAM & STANLEY, LTD., ADAM HILGER, LTD., JAMES SWIFT & SON, LTD., W. WATSON & SONS, LTD., and MESSRS CARL ZEISS (LONDON), LTD. A new model of the Hartridge microspectroscope, a spectrograph of aperture f/2, for use with weak light sources; and an industrial spectrograph taking 8 exposures on a quarter-plate, were shown by Messrs Bellingham & Stanley. Messrs R. & J. Beck showed a collection of spectroscopes and spectrometers for various purposes, including the Beck wave-length spectroscope and the Beck "Girder" spectrometer. Messrs Swift & Son exhibited their new "Utilex" Spectrometer.

Among new instruments exhibited by Messrs Adam Hilger were the all metal quartz spectrograph (Fig. 5), which, including the plate holder, is constructed entirely of metal, as its name implies; and a new model wave-length spectrometer. Of special interest was an infra-red spectrometer in which the usual rock-salt prism is replaced by a fluorite prism,

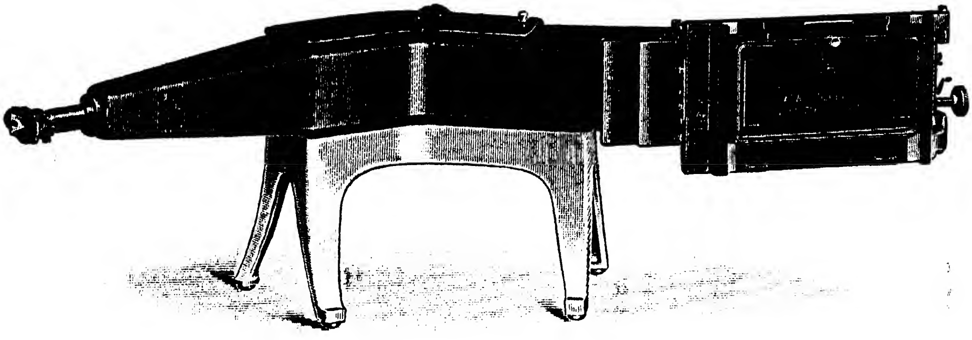


Fig. 5. Hilger All Metal Quartz Spectrograph

thus getting over the difficulty of deliquescence. Stainless steel is used for the concave and plane mirrors in this instrument. The McLennan fluorite vacuum spectrograph designed for research in the extreme ultra-violet, in which the 60° prism and collimator and camera lenses are made of fluorite, was also shown.

COLORIMETERS

The Guild trichromatic colorimeter was exhibited by MESSRS ADAM HILGER, LTD. The Rosenheim-Schuster colorimeter was exhibited for the first time by MESSRS THE TINTOMETER, LTD. This instrument has been designed for the rapid matching of the tints of translucent substances, and is based on the Lovibond colour system.

OTHER APPARATUS

MESSRS KELVIN BOTTOMLEY & BAIRD, LTD., exhibited the K.B.B. Gallois shadowless lamp, in which shadowless illumination is produced by scientifically designed reflecting surfaces, no lenses being employed. This lamp was designed originally for use in operating theatres in hospitals, but its usefulness is by no means limited to such purposes.

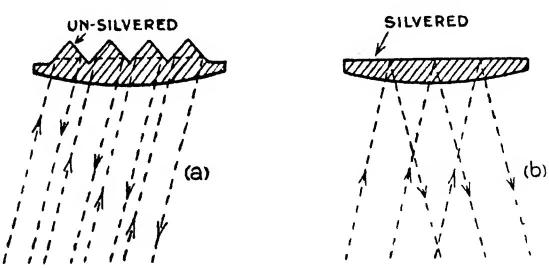


Fig. 6 *a–b*. "Fairylite" Reflectors

Mention must be made of the "Fairylite" reflectors exhibited by FAIRYLITES, LTD. These consist of glass discs or units which are made in various sizes and colours. It will be seen from Fig. 6 (*a*) that the back surface consists of a series of tetrahedral prisms, and that light incident on the reflector is totally reflected at the back surface and emerges parallel to the incident rays. Such reflectors are especially suitable for road signs, since the light

from the headlights of an approaching car is always reflected back towards the driver, and not to one side, as is the case with other types of reflector as at (*b*). Cycle reflectors and road signs composed of Fairylites were exhibited.

NAVIGATIONAL AND SURVEYING INSTRUMENTS.

By Instr. Captain T. Y. BAKER, F.Inst.P., R.N.

The few novelties that there were among the Navigational and Surveying instruments were distinctly interesting.

Messrs E. R. Watts & Son, Ltd., exhibited a model of the Watts-Szepessy Direct Reading Tacheometer (Fig. 1). Ordinarily a tacheometer has, in the focal plane of the telescope, a pair of parallel horizontal wires set apart by an amount equal to one-hundredth part of the focal length of the objective. By reading the number of feet of the surveyor's staff intercepted between these wires and multiplying by one hundred, the distance of the staff from the instrument is determined. This is strictly accurate only when the staff is reasonably vertical and at right angles to the line of sight. When the work is done in hilly country, with the staff on a higher or lower level than the theodolite, the distances are inaccurate owing to foreshortening.

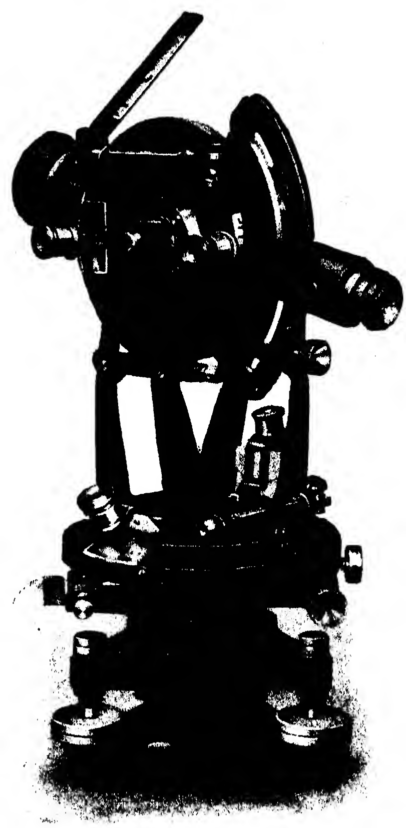


Fig. 1. Watts-Szepessy Direct Reading Tacheometer

In the instrument designed by Mr Szepessy and manufactured by Messrs Watts, the inaccuracies are overcome in an ingenious manner. A glass scale is attached to the body of the theodolite so that it is parallel to the vertical circle. Short lines radiating from the trunnion axis are cut upon this in uniform steps in the tangent of the elevation, the magnitude of the step being presumably 0·01. Through an aperture in the side of the telescope an optical system, consisting of a lens and a prism, produces in the field of view an image of that part of the scale which corresponds to the elevation of the telescope. There is consequently always in the field of view a series of stadia intervals separated by the correct amounts. A fine adjustment of the prism allows one of the stadia lines to be set on a graduation of the staff and the intercept read against the other. Given that the scale is accurately cut and correctly fixed on the instrument there seems to be nothing that can wear or get out of order. The device is shown as an attachment to one of the firm's standard theodolites whose ordinary use is in no way limited.

Messrs Henry Hughes & Son exhibited a machine designed by Messrs Nuschak of Trieste (Fig. 2) for solving mechanically the spherical triangles necessary in nautical astronomy. It does this by actual construction in space of the triangle in question. Two accurately graduated circles correctly set at right angles to one another have other circular rings turning inside them and on the same centre. Upon these rings arcs can be set to represent the polar distance, the co-latitude and the hour-angle; the setting being done in

each case by locating the ring, by means of a hole cut in it, against one of the fixed circles and setting the arc by means of a datum mark on a slider.

The angles having been correctly set, the triangle is locked together by means of a pin passing through holes in two of the rings. Using the ordinary Marc St Hilaire method, the actual zenith distance is found upon the third side of the triangle and can be measured

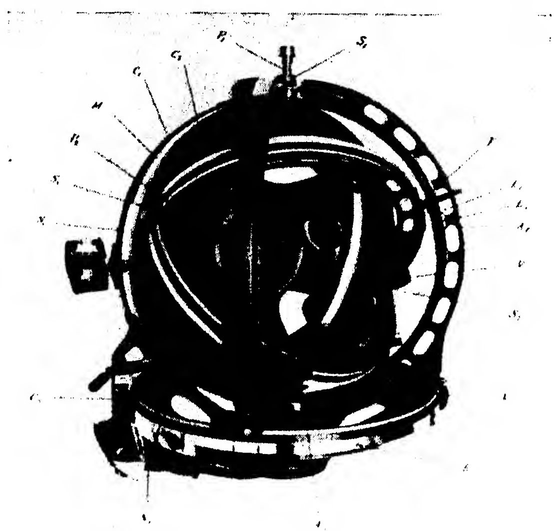


Fig. 2. Nuschak Navigation Machine

by bringing it up against one of the fixed divided circles. In the instrument shown the various moving circles are duplicated so as to deal with the problem of the complete fix obtained from simultaneous observations of two stars.

The value of an instrument of this kind obviously depends upon the accuracy with which it will do its work. The working circles are some eight inches in diameter, and a minute of arc with such a radius is about a thousandth of an inch, so that it is quite clear that, following on the number of operations necessary in the use of the instrument, there is considerable danger of serious inaccuracy.

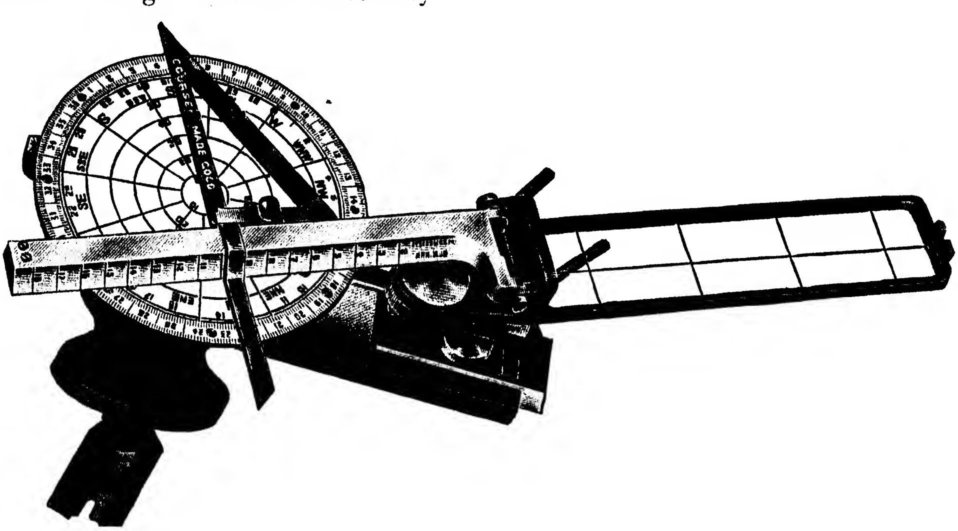


Fig. 3. Wind Gauge Bearing Plate

The Coutinho bubble sextant, made by the same firm, is yet another attempt to utilize a bubble for astronomical observations at sea or in the air. The bubble is viewed by reflection and as seen by the eye indicates the horizontal. The radius of the bubble tube is such that the optical image of the centre of the tube lies at the observer's eye, and in consequence, as the sextant is slightly tilted, the images of the bubble and the sun move together over the horizon mirror.

The latest pattern, made by Messrs Hughes, of the Wind Gauge Bearing Plate (Fig. 3) for use in the air, is well designed from the user's point of view. The parts are robust, and easily manipulated by a man with cold fingers and wearing thick gloves. For example, a clamp is made, not with a small knurled head, but with a projecting lever three inches long. The pitch of the clamping screw is reasonably coarse, so that even after the thread has worn the lever will still clamp home at about the same position.

Messrs W. Watson & Sons, Ltd., showed a modern example of the old fashioned astrolabe, re-designed by Professor C. F. Jenkin of Oxford. In addition to the firms mentioned above Messrs C. F. Casella & Co., Ltd., and Messrs W. Ottway & Co., Ltd., exhibited various instruments used for navigational and for surveying purposes.

METEOROLOGICAL INSTRUMENTS.

By E. G. BILHAM, A.R.C.S., B.Sc.

In an exhibition devoted mainly to physical and optical instruments the absence of any large display of purely meteorological instruments is, perhaps, not remarkable. Nevertheless, meteorologists who visited the Exhibition in the hope of seeing evidence of the instrumental development of meteorology as a branch of physics must have been disappointed. In fact, there were fewer novelties on view this year than last. To those familiar with the trend of development since the War several explanations for this apparent apathy will readily suggest themselves. Only one need be mentioned here. Prior to the War, the design of instruments was largely in the hands of the recognized makers. During and after the War, steady progress towards standardization has been made by the Meteorological Office, and although many new designs have been introduced they have not normally been associated with the name of a particular firm. In an exhibition such as that under notice, there is a natural tendency to concentrate on specialized products, rather than on standardized articles made to the official design, no matter how new and original the design may be.

So much has the present Exhibition been affected by this tendency that the visitor could form very little idea of the actual progress made during recent years in meteorological equipment. The activities of a modern meteorological service comprise observations on the ground, at sea and in the air. For each sphere of operations different types of instruments are required, and those in the last category afford particularly interesting examples of specialized design. At the Exhibition, practically no specimens of these instruments were to be seen, in spite of the fact that all supplies for the weather service of Great Britain are obtained in this country. Exhibits in other branches of physical science were such as to justify the visitor in assuming that he had before him a collection from which he could estimate the present scope and position of the science. It is much to be deplored that such an assumption would have been totally misleading in the case of meteorology.

Having said so much by way of adverse criticism, it is only fair to add that the high standard of British instrument makers was very well maintained by the firms who displayed their meteorological products. In the case of one firm, at any rate, there was evidence of a genuine desire to "adopt, to adapt and to improve."

BAROMETERS AND BAROGRAPHS

MESSRS NEGRETTI & ZAMBRA exhibited two interesting instruments in this class. The first, a large aneroid, incorporated a movement in which two groups of diaphragms operate on the opposite sides of a rocking arm fulcrumed on a spring strut. The resulting rotational movement is transmitted by a lever and chain mechanism to the pointer spindle. A somewhat similar movement has, we believe, been used by the same firm in draught indicators and other instruments for indicating small changes of pressure. The second item is a new barograph in which improved sensitivity and accuracy are obtained by the use of special diaphragms. The control is increased and a new type of zero adjustment is fitted.

SHORT & MASON, LTD., showed their usual comprehensive range of aneroids and barographs, including instruments of the official patterns. The Gold correction slide, made for the Meteorological Office for use on marine barometers, calls for brief description. The object of the device is to perform, mechanically, the ordinary corrections for temperature, gravity and height above sea-level. A small mercurial thermometer is fitted to a brass stock carrying a fixed scale for index error and adjustable scales for latitude and height. By a rack and pinion movement the appropriate readings of height and latitude may be brought into coincidence, and the total correction to the observed barometer reading is then shown, opposite the top of the thermometric column, on a scale graduated in millibars and tenths. The device is eminently suitable for attachment to barometers read regularly by non-expert observers, provided the height of the cistern above sea-level does not exceed 100 feet.

THERMOMETERS AND HYGROMETERS

C. F. CASELLA & CO., LTD., have modified the design of their convenient whirling hygrometer in several respects. The thermometers are now supported in a moulding of black composition, designed to facilitate changing or renewing the thermometers, and a more convenient type of water container is fitted. It would be desirable to ascertain whether the use of a black material for this purpose affects the readings when the instrument is whirled in sunshine. The Assmann psychrometers made by this firm are now supplied with the "insulated" pattern of thermometer, with a view to minimising errors due to parallax.

MESSRS NEGRETTI & ZAMBRA showed some new patterns of mercury-in-steel thermometers and recorders and of electrical thermometers. In precision hygrometry the dew-point instruments manufactured by this firm have proved of great value.

ANEMOMETERS

No new instruments in this class were on view, but attention may be directed to the convenient "portable receiver" for use with electric-contact anemometers, shown by SHORT & MASON, LTD. The receiver, designed in the Meteorological Office, contains the batteries, buzzer and switch, terminals being provided for connexion to the anemometer by means of twin cable.

HISTORICAL EXHIBITS

By E. N. da C. ANDRADE, D.Sc., Ph.D., F.Inst.P.

Two of the exhibits in the historical section were designed to illustrate the early history of modern scientific instruments, namely the air-pump and the balance; one dealt with an instrument of ancient fame, the astrolabe, the use of which has been largely forgotten; and one with the early history of an essentially modern instrument, the gramophone. It may therefore be claimed that, small as it was, the historical section was comprehensive in its interests.

The collection of pictures and models illustrating the evolution of weighing machines, which was shown by the Research Department of Messrs W. & T. Avery, Ltd., gave evidence of a very careful and critical study of the history of a variety of devices. Prompted

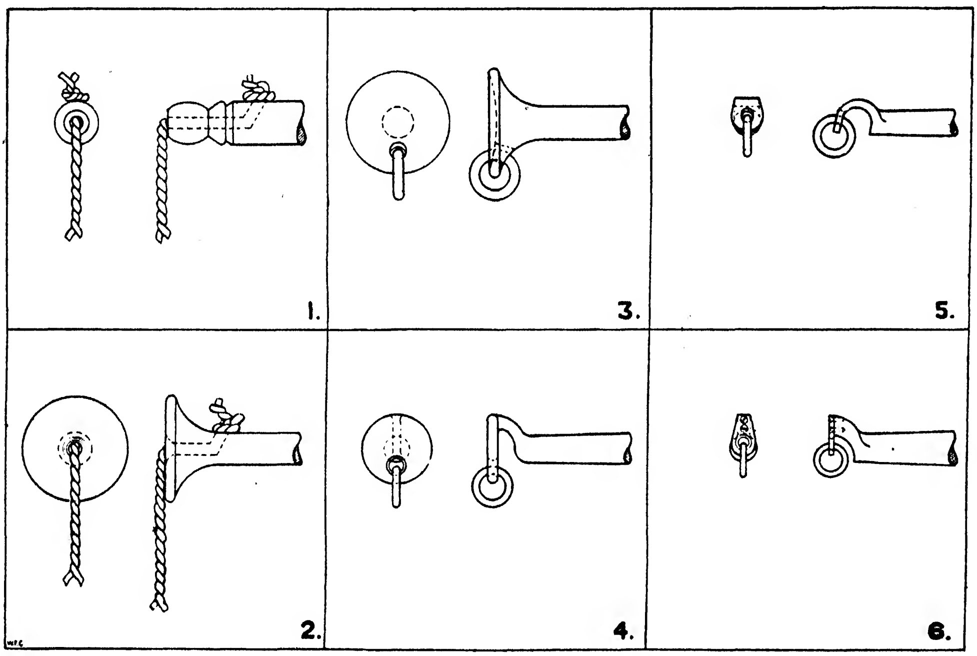


Fig. 1. The Early Evolution of the End Pivot

by Mr W. A. Benton, Messrs Avery have collected at their Soho works (which, incidentally, include the historic workshops of James Watt and Matthew Boulton) a small museum of prints, specimens and models, a selection from which was on view. The exhibition was divided into two sections, one consisting of photographs of ancient records touching on weighing and of certain modern types in which the primitive forms have survived with but little change; and the other of models. Among points of design which were fully illustrated special mention may be made of the types of pivot and suspension. The construction of the cord pivots of the Egyptians, in which the cords were passed through oblique holes in the end of the beam in such a way that the pans were virtually suspended from the ends of the beam, the hole and ring pivot, and the earliest form of knife edge were clearly exposed. Fig. 1 shows some of the early forms of end pivot, in order of development. The comments on the Egyptian balance copied by Lepsius showed how necessary is expert technical knowledge of the process depicted if contemporary representations of

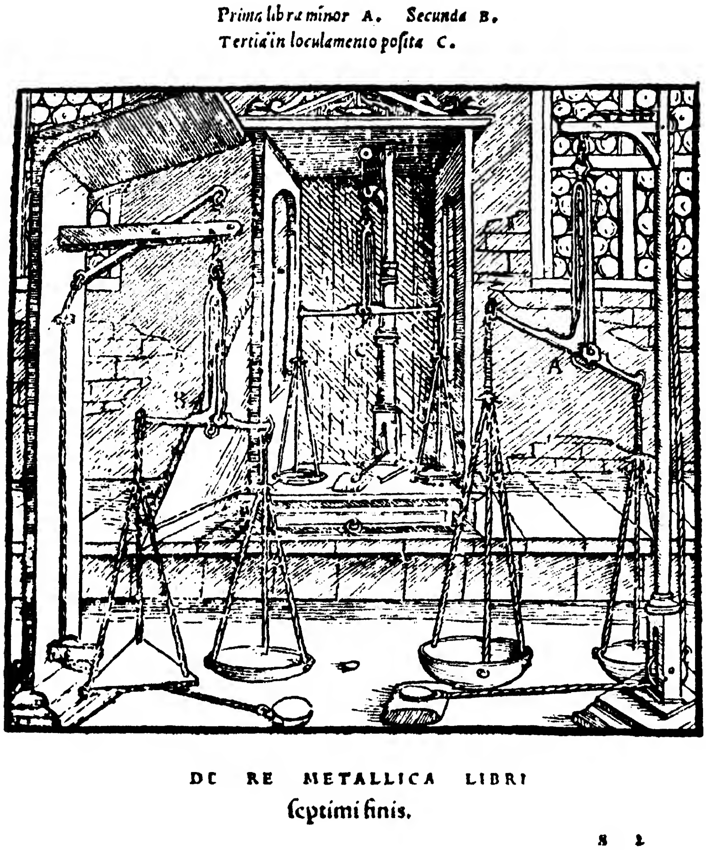


Fig. 2. Early Balances used for Assaying, as illustrated in Agricola's *De Re Metallica*

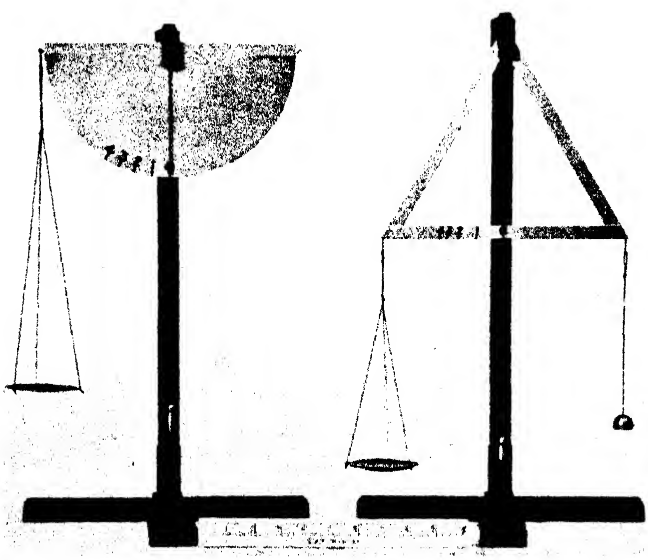


Fig. 3. Self-indicating Weighers Designed by Leonardo da Vinci (1452 to 1519)

the arts and crafts of the ancients are be correctly interpreted, for the downward pointing triangular tongue and the plummet shown in this drawing have been freely misnamed. That sometimes the contemporary artist himself was at fault was shown by the copy of the kylix of Arkesilas, in which the suspension of the balance beam is badly misdrawn. The balances illustrated in Agricola, *De Re Metallica* (1556), by a picture shown in Fig. 2, are

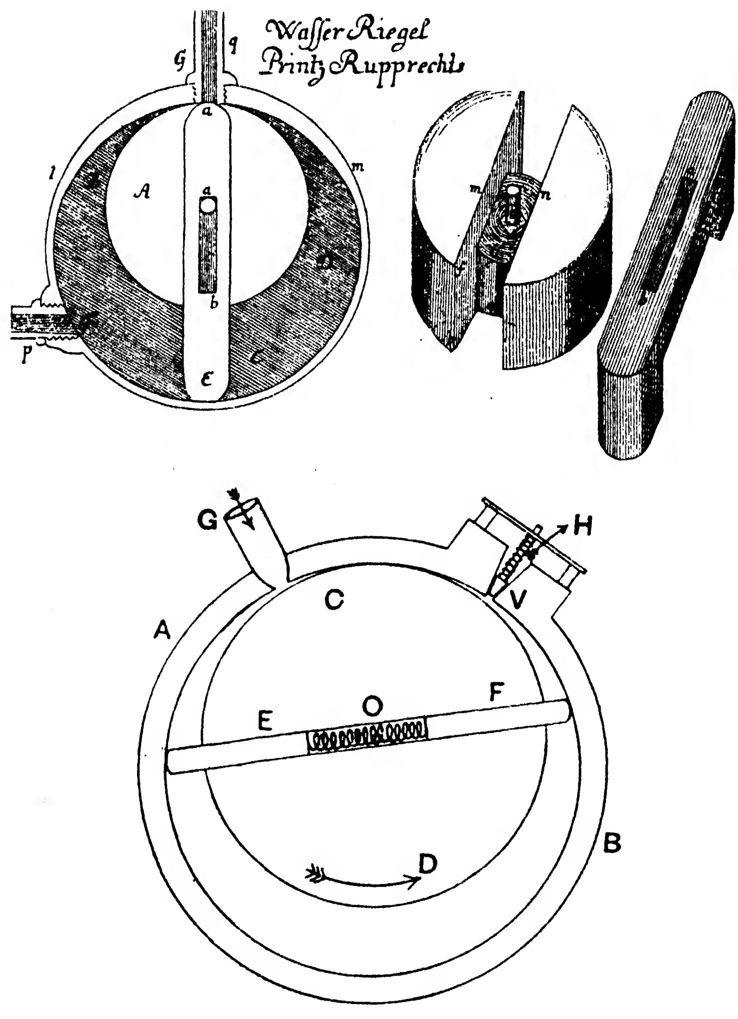


Fig. 4. Above, an early Rotary Pump, Prince Rupert's "Water-Bolt," designed in the middle of the seventeenth century as a water-pump. The picture is from Leupold, *Theatrum Machinarum Hydraulicarum*, 1724.
Below, a modern Rotary Air-Pump, viz. Gaede's *Kapselpumpe*, shown for comparison.

well worthy of study. The smallest and most sensitive is housed in a glazed case, the front of which has been removed for inspection.

The Danish steelyard, in which the fulcrum is displaced, and the Roman steelyard, in which the weight is displaced, were both illustrated, and photographs were exhibited of forms which are still in use among primitive peoples.

Among the models special mention must be made of the reconstruction of da Vinci's celebrated self-indicating weighing machine, the first of its kind; and the beautiful series of section models of mechanisms of the linked lever type, starting with the original Roberval type, and ending with the Phanzeder machine, of which two types were shown.

The series of pictures, exhibited by the writer, illustrating the development of the air-pump, consisted of large photographs of pictures and diagrams from the original books, in his possession, in which the pumps were first described. The series started with the picture in Schott's *Mechanica Hydraulico-Pneumatica* (1658) showing Guericke's first pump: Guericke's own description did not appear until some years later. It continued through Robert Boyle's first and second pump, of which details of construction were shown. Many illustrations from Guericke's *De Vacuo Spatio* (1672) were shown. The pumps of Huygens, Papin and Senguerd and the two-cylinder pump of Boyle led up to the two-cylinder pump of Hawksbee (1709) with which the series closed. There was little change from the time of Hawksbee until the modern type of pump appeared.

Some interesting anticipations of air-pump designs were included in the series, of which one, Prince Rupert's anticipation of the Gaede box-pump, is illustrated in Fig. 4.

Dr A. Ferguson's demonstration of the astrolabe was to some extent a repetition of his discourse to the Physical Society, a summary of which will be found in the *Proceedings**. A fine astrolabe, lent by the Science Museum, was shown, as well as reconstructions of the cross staff and back staff, the uses of which were expounded by the exhibitor.

The exhibit of the Research Department of the Gramophone Co., Ltd. was described by Mr A. Whitaker in his discourse, a report of which will be found on p. 35.

SPECIAL EDUCATIONAL APPARATUS.

By PROF. C. R. DARLING, F.Inst.P., F.I.C.

There were few novelties which could be classified under this heading, although many excellent instruments exhibited on previous occasions were again on view. A brief description of the appliances shown for the first time at this Exhibition is appended.

Clarke's Optical Smoke-Box, which has been described in detail in an earlier number of this *Journal*, was exhibited by Messrs G. Cussons, Ltd. In this device a glass-fronted box is filled with smoke which is prevented from settling by agitating the air occasionally by means of a rubber bulb. Beams of light of varying section are made to enter one side of the box by means of suitable lenses and diaphragms; and prisms, lenses, mirrors, etc. may be pushed from the back of the box so as to intercept the beams. The effect of each of these on the direction of the beams is clearly outlined by the smoke, and by means of scales provided focal lengths, critical angles, etc. may be measured. The apparatus is well designed for illustrating the elementary laws of optics.

Mr C. W. Hansel's Units for constructing apparatus were shown by the inventor. These consist of a number of standardized parts which can be assembled in various ways so as to produce a variety of instruments, after the manner of a "Meccano" set. Adjustments in any direction are provided for, and amongst other applications of the units an optical bench made entirely of the standard parts was on view. Much ingenuity is shown in the design of the components, and junior scholars would no doubt be interested in the building up of the lens-holders, etc. The drawback to the use of contrivances of this kind is that the time spent in the erection cannot always be spared by the teacher, and there is a danger that the student may give more attention to the constructional part than to the subjects for which the finished apparatus is designed. The prototype of apparatus made of standard parts, due to Willis of Cambridge, consisted of very massive units, and were described in Sir Robert Ball's book on *Experimental Mechanics*. Owing to their size, these outfits never became popular, and the neat contrivances exhibited by Mr Hansel are much more suitable for school use.

* *Proc. Phys. Soc.* **39** (1927) 373.

Mr Hansel also exhibited his apparatus for Dynamics. Under this heading a number of devices useful for class work were shown. The characteristic feature was the obtaining of traces of the paths of moving bodies by placing a sheet of "carbon" paper on a baseboard, with a sheet of white paper above, over which the body (such as a ball) moved, pressing the white paper on to the inked paper below and so giving a trace of its path which could be examined and measured. This method of recording the path of moving bodies is neat, clean and satisfactory for subsequent measurements.

A novelty shown by the Record Electrical Co., Ltd., was a "Cirscale" ammeter of good size mounted in a glass case so as to display the working parts. Instruments of this kind are very useful to the teacher when explaining the action, and are much better than models. The sample shown could be used for quantitative work in the presence of a class, each member of which could take the readings. Messrs H. Tinsley & Co. exhibited a cheap, robust mirror galvanometer of good sensitivity, suited for the use of students. It appeared to be designed on satisfactory lines, and should prove to be a useful instrument of its class. It was disappointing to note the infrequent occurrence of instruments, suitable for teaching students above the elementary grade. These demand a degree of accuracy intermediate between the simple and the highly-refined types, and should be designed so as to stand heavy wear and a certain amount of rough treatment. Beyond a few appliances previously exhibited there was little of this class of apparatus on view. Makers would do well to give their attention to this type of instrument, as a ready market would be found for satisfactory appliances of this kind.

Seventh International Congress of Photography, London, 1928.

The Seventh International Congress of Photography will be held in London, from Monday, July 9th, to Saturday, July 14th, 1928, both dates inclusive, under the auspices of the Royal Photographic Society. The previous six Congresses were held in Paris (1889, 1900 and 1925), in Brussels (1891 and 1910), and Liège (1905). The Congress is being organised in co-operation with the Permanent Committee of Photographic Congresses, by a Committee of representatives appointed by the leading Scientific and Photographic Societies of Great Britain, at the invitation of the Royal Photographic Society.

The Congress will include exhibitions, meetings, special lectures and addresses, and visits and excursions to various places of interest. Subscriptions are as follows: Associate Members, 10/6 (not eligible for a copy of Proceedings); Full Members, £1/1/0 (eligible for a copy of Proceedings); Founder Members, Business and Manufacturing Firms and Corporate Bodies £5/0/0 and upwards (eligible for a copy of Proceedings).

Inquiries may be addressed to the Hon. Secretary of the Congress, Dr Walter Clark, Science Museum, South Kensington, S.W. 7. Forms of application for membership, accompanied by subscriptions, should be sent to the Hon. Treasurer, International Congress of Photography, 35, Russell Square, London, W.C. 1.

The full text of all papers to be presented at the Congress, accompanied by abstracts, both in duplicate and typewritten, must be submitted to the Hon. Secretary before June 1st, 1928.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V | MARCH, 1928 | NO. 3

ARTIFICIAL DAYLIGHT.

By J. W. T. WALSH, M.A., D.Sc., F.Inst.P.

A DISCOURSE GIVEN ON 12TH JANUARY 1928 AT THE EIGHTEENTH ANNUAL EXHIBITION OF THE PHYSICAL AND OPTICAL SOCIETIES

THE subject of artificial daylight has only recently received any considerable measure of attention, although units designed to give artificial light of the same colour as natural daylight have been in existence for several decades at least. This is probably due to the fact that, for electric lamps, the production of artificial daylight at a reasonable cost was out of the question until the advent of the gas-filled lamp. This type of lamp is not only inherently more efficient, but the light it gives is so much whiter than that given by the vacuum lamp that the loss incurred in the production of artificial daylight is much reduced. To reduce these rather general statements to figures, it may be mentioned that an artificial daylight illumination which could be produced with gas-filled lamps at an expenditure of about 100 watts, would require nearly double that amount of energy if produced by means of tungsten filament vacuum lamps.

The term "daylight" is, in itself, an incomplete definition. There is a general impression that the colour of daylight is fairly constant, but very simple experiments suffice to show that this is far from being the case, and the following table shows the range covered under ordinary everyday conditions:

	Red	*Green*	*Blue*
Noon sunlight taken as	100	100	100
Overcast north skylight	89	92	119
Blue north skylight	78	84	138

The fact that such large variations as these in the composition of daylight are generally quite unsuspected is due in the main to the fact that the eye finds it very difficult to compare two lights unless they are presented to it side by side. It will be clear, however, that when it is desired to imitate daylight artificially, some convention must be arrived at as to the exact hue of the daylight to be imitated. And here the use to which the artificial daylight is to be put must obviously be given careful consideration. For many operations in which the matching of coloured substances, such as oils or dyes, is an essential process, the light frequently adopted as standard is that from an overcast north sky.

In order that such processes may be carried on after dark, the artificial light provided must be as close an imitation as possible of this particular form of daylight. For other purposes the colour of direct sunlight at noon on a clear midsummer day is chosen. This light is distinctly richer in the red and yellow rays, and it can therefore be produced with a smaller loss of efficiency.

The only really satisfactory definition of the hue of a light is its spectral distribution curve such as that shown in Fig. 1. The abscissae are the wave-lengths, or frequencies, of the light waves forming the different parts of the spectrum, and the ordinates are the corresponding intensities. It will be clear that two lights having identical spectral distribution curves will be of exactly the same colour, and the degree of similarity between the curves indicates the degree of similarity between the lights. This statement must, however, be qualified by the remark that lights which are actually quite different in composition *may* appear identical to the eye. For instance, two lights which consisted respectively of red rays of wave-length 0·61 μ and of blue rays of wave-length 0·49 μ, would, if mixed in the correct proportion, give a light which would appear to the eye to have precisely the same

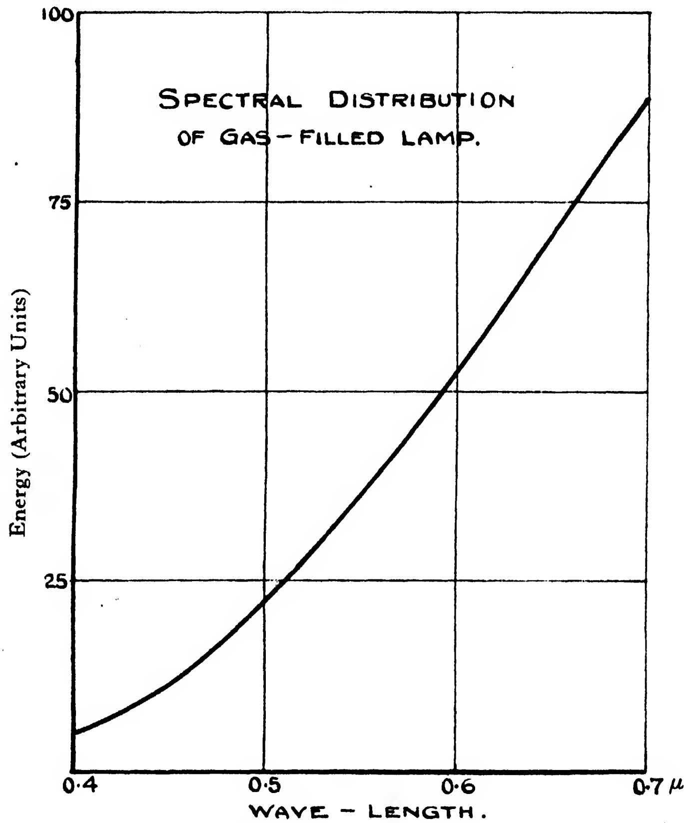


Fig. 1. Spectral Distribution Curve for Gas-Filled Lamp

colour as daylight. The difference between true daylight and this mixture of red and blue would, however, be at once apparent if both lights illuminated a piece of paper which reflected only the greenish-yellow light in the spectrum. This paper would, of course, appear of its ordinary colour when illuminated by the real daylight, whereas it would appear black when illuminated by the red-blue mixture, simply because this mixture contained none of that part of the spectrum which the paper was able to reflect.

This simple example will show the difference between what may be called a "sensation daylight," *i.e.* a light which appears to the eye to be of the same colour as daylight, and a "spectral daylight," in which the distribution of the light throughout the spectrum is as far as possible the same as in natural daylight. Since objects are seen, generally, by the light which they reflect to the eye, it is clear that *coloured* objects will appear to have the same colour when seen by natural daylight and by artificial daylight only if the two lights are

similar in spectral distribution. Uncoloured, *i.e.* white and grey, objects, however, will appear the same under a natural daylight and under any form of sensation daylight.

This distinction is a very important one because, although the mixture of pure red and pure blue lights cited above was an extreme case, it will be clear that it is quite easy to produce a sensation daylight which, although it contains all the colours of the spectrum, contains them in quite other proportions than those in which they are present in natural daylight.

In order to obtain, from any artificial illuminant, light of the same spectral distribution as daylight two methods may be adopted, at least theoretically. In the first, the additive method, two or more illuminants are used simultaneously, one of the ordinary kind with an excess at the red and yellow end of the spectrum, and the other a special type of lamp the light from which is mainly in the green, blue and violet. If the various components

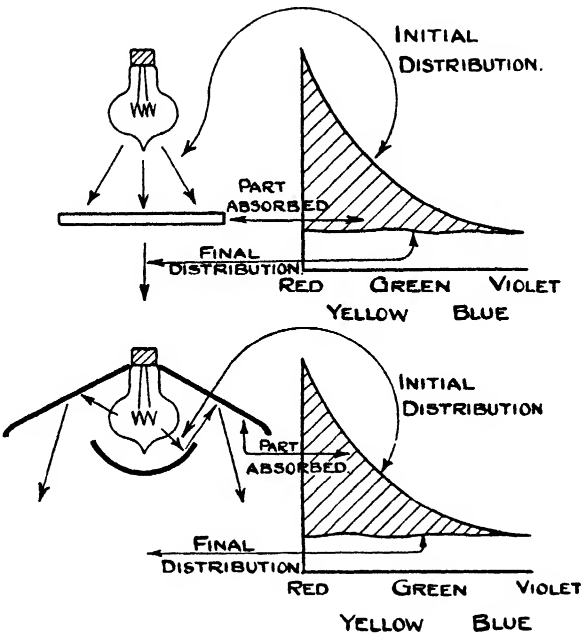


Fig. 2. Principle of the Subtractive Method of producing Artificial Daylight

can be suitably proportioned, the resulting mixture may be a passable artificial daylight. This method is, however, not very easy of practical achievement, and the method of artificial daylight production now adopted almost universally is the "subtractive method," in which the spectral distribution of the light from the source is changed by the removal from it of the excess amounts in the red and yellow parts of the spectrum. This removal can be effected, either by passing the light through a coloured medium such as glass or gelatine, or by causing the light to be reflected from a coloured surface. The principle of these two methods will be seen from Fig. 2. Each of these methods has been applied practically in units now on the market.

It will be clear, from the very nature of the subtractive process, that there must be a loss of efficiency in the production of artificial daylight. By no practical means is it possible to increase the amount of blue or violet component in the light given by a lamp (apart from fluorescence). The proper proportions, therefore, can only be obtained by removing the excess in other parts of the spectrum, and this excess must necessarily be wasted. This

point may appear too obvious to need mention, but it is remarkable how frequently its implications are not appreciated and claims of exaggerated and perfectly impossible efficiencies are made and receive credence from the general public. To give actual figures, a theoretically perfect imitation of noon sunlight can be obtained from a gas-filled lamp with a maximum efficiency of about 25 per cent.

There are, however, very great practical difficulties in the way of producing a really perfect imitation of any selected form of daylight. Anyone who has experience of glass-making will realize that the production of a glass which will give *exactly* the required absorption at every part of the spectrum is a practical impossibility. The same is true even if a combination of two glasses be used, so that it becomes necessary to select a glass which gives the nearest approximation to the required result and which can be produced in practice. Much research has been devoted to the production of glass of this kind and several types have been developed in this country and abroad.

The same remarks apply, at least in principle, to the type of unit in which a coloured reflector is used to absorb the excess of red and yellow. Here, by the use of what may be described as a "mosaic" of various colours, it is possible to obtain a closer approximation to the desired result, but unfortunately only at the expense of a large total absorption.

In either case, then, something less than perfection must be accepted, and once this has been conceded it is clearly logical to consider whether, by allowing further small departures from perfection, the efficiency of the method cannot be improved. It will be clear, from the form of the distribution curves of the artificial light, that the efficiency will depend very greatly on the exact point in the blue end of the spectrum which is chosen as the limit of coincidence of the curves for the natural and for the artificial daylight. For instance, in calculating the efficiency figures just quoted, it was assumed that coincidence was required as far as the very limit of the visible spectrum, *i.e.* a wave-length of 0·42 μ. If, now, it were agreed that exact coincidence was unnecessary beyond, say, 0·45 μ, the efficiency would be improved from 25 per cent. to 33 per cent. Having regard to the fact that real daylight, even of one of the varieties described, is itself variable, and to the limitations in the production of coloured absorbing or reflecting media having any specified absorption curve, it is clearly unreasonable to sacrifice so much in efficiency for the sake of coincidence of the curves at the far point of the violet end of the spectrum. The problem then becomes one of deciding how much can be conceded, and the answer necessarily depends on the use to which the artificial daylight is to be put. Even when this has been defined, there is room for a good deal of private judgment in the determination of the limits to be allowed on the theoretical curve, and it is greatly to be desired that some specification should be prepared for the limits permissible in the spectral distribution curves of artificial daylights of various classes. This specification should be drawn up by an authoritative body capable of investigating the matter thoroughly in order to determine what is necessary for different types of work.

Broadly, the uses of artificial daylight may be put into two main classes, *viz.*, colour matching, and general illumination. Of these the most exacting is, of course, the colour matching of coloured pigments, dyes and dyed fabrics and the like. It has always been recognized that certain colours cannot be matched by ordinary artificial light. Purples, for instance, such as the purple of a bunch of violets and of certain pansies are notoriously difficult in this respect. Other colours show similar effects to a less extent. For the accurate matching of certain dyes a close approximation to a true daylight spectral distribution is essential and trades in which colour matching is an essential process demand artificial daylight units of the highest grade as regards spectral distribution. As has been pointed out already, it is not possible for such a unit to have a very high efficiency as regards total light output.

The requirements of a unit suitable for general illumination are, naturally, much less exacting. The use of this form of daylight in drawing offices, in clerical offices and in the home is now becoming more and more general. It has been found particularly valuable in rooms which receive insufficient natural daylight over the whole or part of the working space, so that artificial light has to be used either continuously or for very long periods, especially in the winter. The disagreeable sensation experienced by most people when working in what is generally called a "mixed light," *i.e.* a mixture of ordinary artificial light with daylight, can be entirely obviated by using artificial daylight units instead of lamps of the ordinary type.

As regards the use of artificial daylight for ordinary purposes, such as reading, opinions differ very widely. There is no doubt whatever that many critical observers definitely prefer the artificial daylight and state that they can work with much greater comfort and with less strain by artificial daylight than by ordinary artificial light. Tests have been carried out with the object of discovering any scientific explanation of this preference, but so far the results have been inconclusive. Moreover it cannot be denied that certain people definitely dislike the artificial daylight. It appears to be largely a matter of personal opinion, and that is all that can be said on the matter at present.

There is, however, very little doubt that nearly everyone prefers to work by natural daylight rather than by ordinary artificial light, so that there must be some explanation for this preference other than the mere colour of the light. An attempt is being made by the Illumination Research Committee to find out if the distribution of natural daylight is preferred to that usual with artificial lighting. A room has been fitted up at the National Physical Laboratory so that the same illumination can be provided by:

(*a*) Semi-indirect lighting with vacuum lamps;

(*b*) Semi-indirect lighting with artificial daylight (blue-bulb) lamps;

(*c*) Artificial window lighting with vacuum lamps;

(*d*) Artificial window lighting with artificial daylight lamps.

To obtain the artificial window lighting, the window of the room has been covered with a diffusing material, and lamps have been so arranged on the outside that the brightness of the window as seen from within is practically uniform and the distribution of light in the room corresponds to that from a window with an unobstructed view of a uniform sky.

It is very difficult to get figures which will show any definite superiority for one system of lighting as compared with another, but there seems to be a very decided consensus of opinion as regards personal preference. All who have worked in the room, as well as those who have simply inspected it, say that the artificial window giving light of daylight colour is much preferable to any of the other systems. It is, of course, inefficient compared with most ordinary lighting systems, but there are certain types of rooms, in which the circumstances are more or less special, where it might well repay adoption.

It will be clear that for general illumination purposes it is probably unnecessary to aim at any very close approximation to spectral daylight—a sensation daylight is all that is required—and therefore a simple unit of higher efficiency than is possible for a colour-matching unit may be employed. In fact, in the experiments just described, the now familiar gas-filled lamps in blue glass bulbs were used.

The spectral distribution curve of a lamp of this type is shown in Fig. 3 *a*. The curves for other units, all of which employ some form of bluish glass as the absorbing medium, are shown in Figs. 3 *b* to 3 *f*. The horizontal line represents overcast daylight, which has been taken arbitrarily as 100 per cent. throughout the spectrum. The curves show, for each type of unit, the percentage throughout the spectrum for this unit on the same basis. These curves have been drawn from data kindly supplied by the manufacturers.

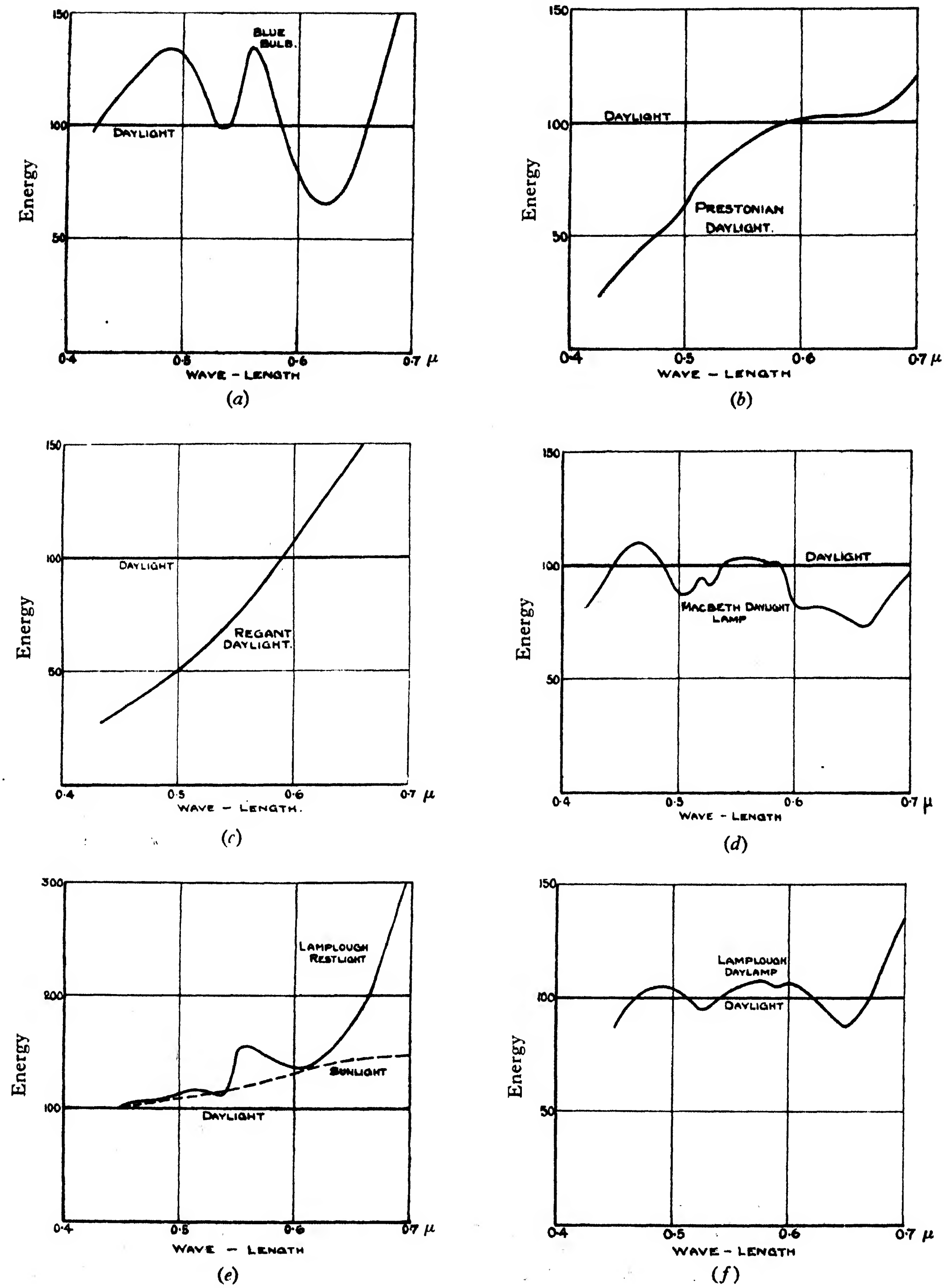


Fig. 3. Spectral Distribution Curves of various Artificial Daylight Units relative to Daylight (from data supplied by the manufacturers)

Another unit, the Sheringham, is also subtractive, but is of the reflector pattern. The spectral distribution curve of this unit is shown in Fig. 4.

An altogether different type of artificial daylight lamp is the special daylight gas mantle, the curve for which is shown in Fig. 5. In this case the subtractive method is not employed, but instead the mixture used for impregnating the mantle is modified in composition so that the spectral distribution approximates to that of the daylight due to a low sun. The light output of the special daylight mantle is about 80 per cent. of that of the ordinary mantle.

Finally, the use of spectacles for producing the effect of artificial daylight may be mentioned. It is clearly immaterial whether the colour of the light be changed before or after it reaches the object to be viewed, and spectacles for producing the effect of artificial daylight were patented by H. E. Ives several years before the War. There is little doubt that with modern light sources such glasses might be found very useful for certain purposes. One important matter, mentioned in Ives' patent specification, is the necessity for preventing

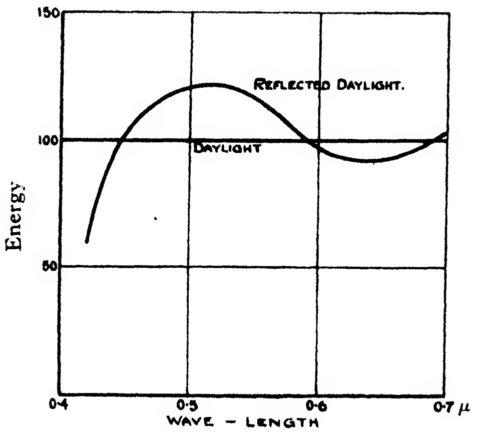


Fig. 4. Spectral Distribution Curve of Reflector Artificial Daylight Unit (Sheringham Patent). (See *Illum. Eng.*, **13** (1920) 40)

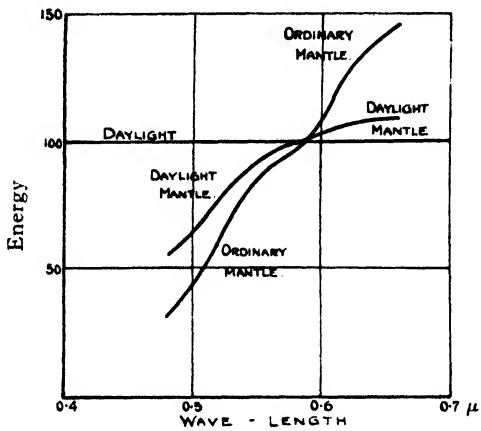


Fig. 5. Spectral Distribution Curves of Ordinary Gas Mantle and Artificial Daylight Mantle (Patentees, C. J. D. Gair and the S. Metropolitan Gas Company)

any stray light from entering the eye. For this reason the glasses should be used in the form of close-fitting goggles with opaque black sides.

Some of the purposes for which artificial daylight is especially suitable have been mentioned above, but there is one important application which has not yet received all the attention that it deserves. The criticism is often heard from art lovers that the galleries containing our priceless national collections of pictures are closed during a very large part of the only time during which many people are able to visit them. This is especially true in the winter months, and there is no doubt that the number of visitors to the principal galleries would be much greater if the pictures could be seen in the evenings. To show them by ordinary artificial light would, however, be far from satisfactory. Many of the pigments would not appear true under these conditions and some form of artificial daylight is clearly called for. Certain of the provincial and smaller London galleries have been lighted in this way, and the time has surely come for the great national collections to have their value to the art-loving public increased in a similar manner.

In conclusion it may not be out of place to mention some purposes for which artificial daylight is *not* suitable. The illuminating engineer who installed such light in a ball-room would thoroughly deserve the unpopularity which would certainly be his. For many such

purposes even the ordinary gas-filled lamp is too rich in the blue rays and an amber-tinted lamp is often used in consequence. For motor-car headlighting, again, it has been demonstrated that there is no advantage in the use of a blue-bulb lamp. These, however, are specialized branches of illuminating engineering of comparatively minor importance. The fields in which artificial daylight may legitimately be applied are vast and are being extended daily, and if this lecture has done anything towards helping in the intelligent application of this comparatively novel aspect of illumination, its purpose will have been fully served.

NOTES UPON THE MECHANICAL DESIGN OF SOME INSTRUMENTS SHOWN AT THE EXHIBITION OF THE PHYSICAL AND OPTICAL SOCIETIES, 1928. BY A. F. C. POLLARD, A.R.C.S., A.M.I.E.E., F.INST.P. Professor of Instrument Design at the Imperial College of Science.

AN examination of the new instruments which were shown at this year's Exhibition of the Physical and Optical Societies indicated that the number of mechanisms successfully designed on kinematical principles, the useful details of which it is mainly the present object of these notes to place on record, did not exceed in interest those found in the Exhibition of last year. Nevertheless it is hoped that it will be possible in future years to devote such notes as these more to descriptions of ingenious mechanisms themselves rather than to the kinematical design of their elements, which will then be regarded as a *sine qua non*, much in the same way as the ordinary design of the lower pairs of mechanism is regarded to-day.

Amongst the high-class exhibits of Messrs Ross, Ltd., the new model of the Ross Kinematograph Projector offers many details of mechanical interest, a few of which will be noted.

The projector is shown in Fig. 1, and is of the usual robust and well-designed construction of the Ross projectors, but a number of improvements have been recently introduced which place this instrument in the highest rank of its class. Perhaps the most important feature of the projector, a description of which must not occupy much space here, is the source of illumination and the projection lens. The arc lamp is backed by a 10-inch mirror, and this, together with the lens, has been regarded as a single unit and computed as such. The carbons of the arc, known as high intensity carbons, are cerium loaded, and emit an intense radiation at 100 amperes, richer in the blue end of the spectrum and poorer in the red as compared with the ordinary arc. In consequence of this the light is whiter and the heat generated is less per watt consumed. But if considerations of economy require a lower current consumption, ordinary carbons at 20 to 30 amperes can be used. This firm have very carefully considered the design of the lens, which is termed the Ross D.P.L. Projection Lens, and have taken full advantage of the "High Intensity Mirror Arc." Coarse adjustment is provided by sliding the lens in a clamping sleeve; the lens and sleeve can then be moved together through a fraction of an inch by giving the focussing lever a movement of 90 degrees, which serves as an extremely fine adjustment.

The gate aperture and projection lens are each fixed to an upright cylindrical bar, plainly seen in the figure, directly in line with one another, while the mechanism carrying the intermittent sprocket, top and bottom sprockets and film track with pressure springs is arranged on a frame which slides up and down these bars for the purpose of masking the picture. The loops of film above and below the intermittent sprocket remain a constant length, and no allowance need be made in their length for racking; moreover the film is not pulled through the gate when racking, as the film track moves with the film.

The motor is mounted underneath the machine in a swinging cradle, originally introduced by Messrs Ross, which ensures that the tension of the belt is maintained constant. The belt passes over the flywheel, seen to the right and below the projecting lens in Fig. 1 and separately shown in Fig. 2.

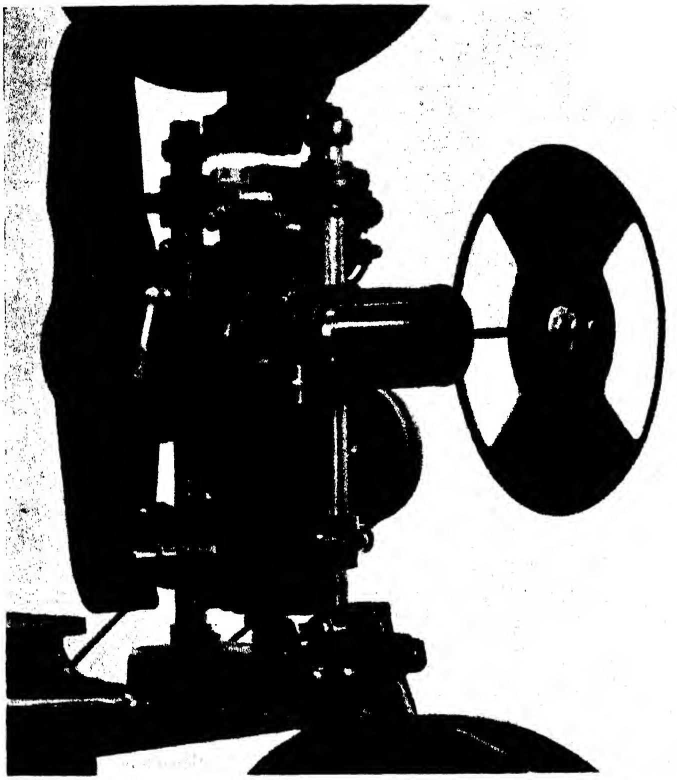


Fig. 1

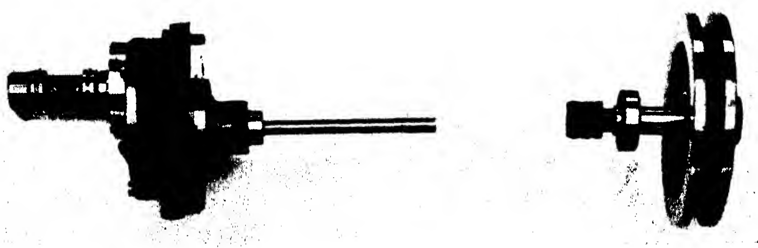


Fig. 2

The flywheel is fitted to the main spindle, which ends in a worm driving a vertical spindle and rotates in two double row ball bearings. The spindle is hollow to allow the cam shaft from the Maltese cross box, seen to the left in Fig. 2, to pass through it to the extreme end of the main spindle, where the cam shaft is fixed by a set screw engaging with a flat cut upon it.

The Maltese cross movement is formed as an interchangeable unit enclosed in an air-tight oil bath. The Maltese cross, with its spindle and the cam spindle itself, run therefore in oil.

The Maltese cross is made from oil hardened Chrome Vanadium steel in one piece with its spindle, machined and accurately ground, and the squareness of the cross is optically tested. The striking pin actuating the cross is fitted with a roller and shows the care with which this mechanism has been designed by the makers. The intermittent sprocket attached to the cross is made of tool steel hardened and tempered. The teeth are cut out of the solid and ground true after hardening, and the makers claim that the continuous play of the film over the teeth does not undercut the steel, which would be fatal to the action of this component. Not only this sprocket but all sprockets in the machine are tested optically for accuracy of spacing and correctness of the standard dimensions.

The vertical shaft, which is driven by worm gearing from the main spindle, has keyed to it gears which actuate a centrifugal friction clutch for an automatic cut-off, the shutter spindle, the top and bottom sprockets and the universal joint driving the take-up. All the gearing is of the helical type, for which the makers claim smoothness of action and absence of the noise which is characteristic of inaccurately finished spur or bevel gearing, indicating a want of constant velocity ratio with attendant vibration.

There can be no doubt that the makers have shown wisdom in their choice of the form of gearing for such an apparatus as a kinematograph projector.

The main driving spindle and the shutter spindle are constrained by ball bearings, but all the other bearings in the mechanism, with the exception of a few thrust ball bearings, are long phosphor bronze bushes. These bushes must necessarily be carefully lapped or ground to very fine limits, and the makers have given themselves a lot of unnecessary and expensive labour here.

Ball bearings have been used with success by the engineer for such a long time that instrument makers should make use of this extraordinarily beautiful and comparatively cheap form of turning pair whenever possible. In the ancient form of journal and bushing, which must necessarily be used for great loads, there must always be a metal clearance to ensure a running fit. This fit is expensive to manufacture, and even when the clearance is filled with oil the shaft, though running at high speed, is capable of minute lateral displacements. This cannot take place with the ball bearing. There is true metal contact with the balls and races, the friction is reduced to rolling friction, which is a fraction of sliding friction, and oil does not reduce the rolling friction of a ball bearing and need not be used for that purpose.

Some people still persist with indefinite notions that a journal running in ball bearings is incapable of standing high speeds without vibration and destructive wear and tear, but it should be remembered that a number of internal grinding spindles of cylindrical grinders are now designed with ball bearings, and these frequently attain speeds of over 22,000 revolutions per minute. Moreover these spindles are capable of grinding more perfectly cylindrical holes, with finer limits, than can be accomplished with the old form of long bushing, which evolves a lot of heat and generally results in differential thermal expansions of the housing, bending of the spindle and final jamming.

It is however refreshing to find that instrument makers are gradually realizing the perfection of the motion which can be attained so readily, and so comparatively cheaply, by the use of the sphere and plane or the sphere and cylinder.

Messrs W. Ottway and Co. Ltd. exhibited a screw measuring machine built to the designs of Professor W. E. Dalby. In this instrument the carriage, in which the screw to be measured is fixed, slides under the reading microscope with great perfection of motion, attained by two fixed ground cylinders rolling on balls resting in V grooves. The cylinders parallel to one another are fixed to the carriage, and when the carriage is in position the axes of the cylinders parallel to one another and to the three rows of balls lie in a plane inclined to the horizontal plane. The lower cylinder rests upon balls which roll in two separate

V grooves in the framework of the instrument, while the upper cylinder rests upon balls which roll in a groove parallel to the two former grooves. Thus the carriage can be lifted off by hand, replaced upon the balls and enjoys rectilinear motion with minimum friction. The carriage abuts against the end of a fixed micrometer screw and the whole instrument is slightly tilted, so that gravity causes the carriage to abut against the micrometer with constant pressure. The detail of design to which it is desirable to call attention is the manner in which the balls are prevented from falling out of the V grooves.

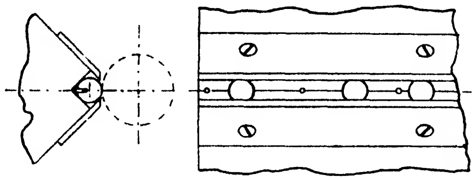


Fig. 3

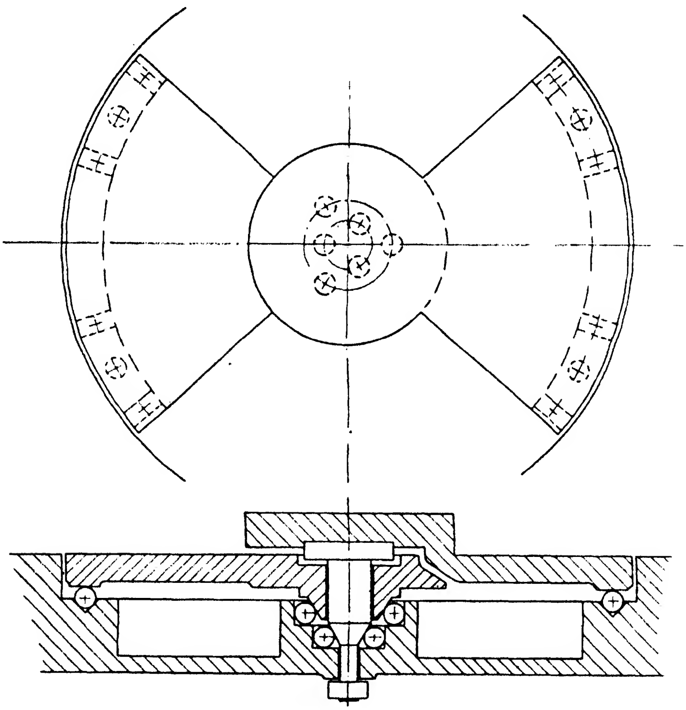


Fig. 4

As will be seen from Fig. 3 two brass strips with chamfered edges which overlap but do not touch the balls are screwed to the sides of the groove, so that if the frame of the instrument is turned upside down the balls cannot fall out. At intervals along the length of the groove pins are inserted and one ball is housed between each pair of pins. In this simple way the balls are prevented from random motion along the groove and there are always some balls in position for the cylinders of the carriage to rest upon.

On p. 190 of vol. IV of this *Journal* the design of a ball bearing for the prism table of the Hilger Spectrometer was described, and this firm has now gone a step further in the application of geometric ball centres to precision instrument work, which is entirely due to investigations carried out by Mr Dowell. Fig. 4 represents the section and plan of the two axes in the latest model of the Laby X-ray Spectrograph which was exhibited by Messrs Adam Hilger Ltd.

The spindles, one of which embraces the other with wide clearance, are conical at their lower ends to form ball races, and the balls are shown resting in circular recesses cut in the frame of the instrument. This part of the design is similar to that of the spindle of the prism table of the Hilger Spectrometer referred to above. But in order to prevent rotation of the rotating components about a horizontal axis, a circular **V** groove is cut in the frame to function as a ball race, and the opposing surface of the moving component is ground flat and rests upon two balls in the groove. It was interesting to learn from Mr Dowell that the circular **V** groove is cut in the cast iron of the frame, and that the surface of the ball races thus formed in cast iron are sufficiently smooth for the balls to roll with the necessary accuracy.

Amongst the other first class products of this firm the accurate workmanship of the goniometer fitting of Muller's X-ray Goniometer-Spectrograph was worthy of close inspection. This fitting is illustrated in Fig. 5.

The extremely accurate workmanship necessary will be appreciated when it is realised that during extreme motion of the two circular slides at right angles to one another the point of the style must not leave the centre of the system once it has been set there. In the first instance it is essential that the circular slides shall be truly circular, but it is evident that the makers could have saved themselves a great deal of expensive fitting if they had adopted kinematical design throughout this fitting.

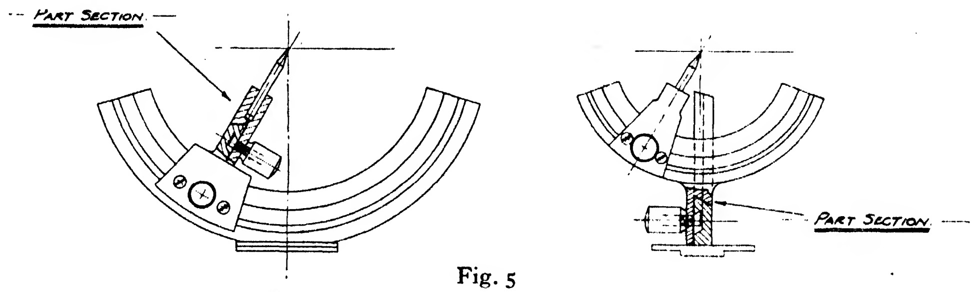


Fig. 5

Instead of constructing expensive male and female half dovetail slides, it would have been simpler to form the metal arcs of rectangular section, with one truly plane vertical face and one truly cylindrical inside surface. Each sliding component could then contact with these true surfaces—by means of screws with hardened and polished hemispherical ends—at five points, three on the plane surface and two on the cylindrical surface, thus leaving the required degree of freedom, *i.e.* rotation about the axis of the cylindrical surface. The screws of the larger sliding component would enable the axis of the lesser cylindrical surface to be adjusted to intersect the axis of the greater cylindrical surface at right angles, which is the necessary condition for the style point, once set by the five adjusting screws of the lesser sliding component to remain at the centre of its own resultant spherical motion. After adjusting the ten screws they could be locked, and the expense of accurately fitting would be thus avoided.

The metal arcs should be constructed from steel, hardened and ground, or better still from a forging of "Staybrite," which does not require hardening and is non-rusting. The necessary pressure at the five contacting points could be produced by an opposing screw, mounted in a stiff spring attached to the sliding member, contacting with the upper surface of a 90° **V** groove cut in the other and comparatively unfinished vertical face of the steel arc. Further, the pressures upon the points could be made approximately equal to one another, by inclining the axis of the clamping screw to the horizontal at an angle whose tangent is two-thirds, the upper sloping face of the groove sloping of course at the same angle to the vertical.

NOTE ON A SPECIAL DIAL FOR TIME-PIECES TO BE USED WITH ROTATING WIRELESS OR OTHER BEACONS.

By R. L. SMITH-ROSE, D.Sc., Ph.D., A.M.I.E.E. National Physical Laboratory.

[*MS. received*, 30*th September*, 1927.]

ABSTRACT. In the near future it is probable that the rotating beacon transmitter will find wide application as a means of obtaining wireless bearings for navigation purposes. The following paper describes some specially designed "compass-card" dials for watches and chronographs used in connection with such beacons.

One application of wireless signalling as an aid to navigation on sea or in the air, or for land survey purposes, is to employ a directional wireless transmitter which rotates about a vertical axis at a uniform speed. The signals emitted by such a transmitter may be intercepted by a suitable receiver from which a bearing of the transmitter may be obtained.

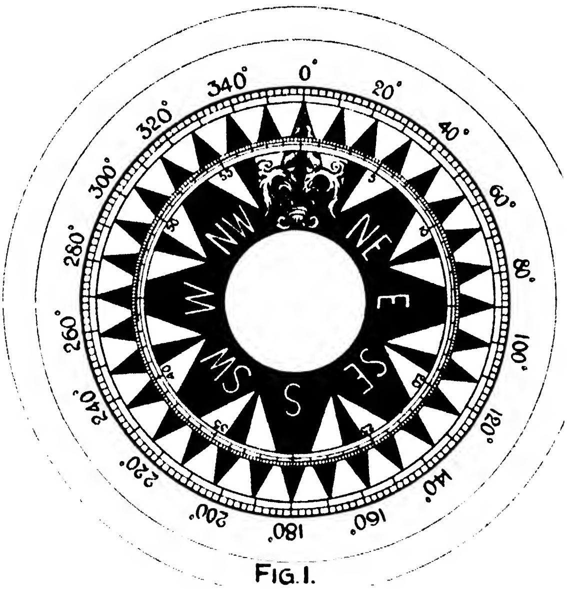


Fig. 1.

The directional property of the transmitter combined with its rotation will cause the received signal to vary in intensity with time. The instant at which the signal intensity passes through its maximum or minimum value is employed for the purpose of obtaining a bearing observation. The method commonly employed is to measure the time at which this occurs after a characteristic signal given by the transmitter or beacon, which indicates that the direction of radiation given by the beacon has some definite relation to the geographical or magnetic meridian. From this time observation and a knowledge or subsequent measurement of the time of rotation of the transmitter, the bearing may be deduced by a simple calculation.

For example, suppose that the observation is made upon the minimum of signal intensity at the receiver, and that a definite characteristic signal is emitted when the transmitter is radiating its minimum signal in the geographical north direction. If the time in seconds is

observed from this signal until the signal at the receiver passes through its minimum value, then the bearing of the transmitter from the receiver is obtained by the following calculation:

$$\text{Bearing} = \frac{\text{Time from North signal to minimum signal} \times 360^\circ}{\text{Time of rotation}}$$

The time of rotation of the beacon can be measured by observing the interval between two successive north-point signals.

Fig. 2

If now, the time of rotation is exactly one minute or sixty seconds, it is evident that the rotation takes place at the rate of six degrees per second, and that, therefore, the bearing in degrees is obtained by simply multiplying the measured time from the North signal to the minimum signal by six. It is usual to make this time measurement with the aid of a chronograph or stop-watch, the main index hand of which rotates once in sixty seconds. The watch is started at the North signal and then either stopped or the position of the index hand observed when the signal passes through its minimum. If as is usual, the beacon gives two minimum signals in each revolution, successive bearing observations may be made at thirty seconds interval or 180° apart.

To avoid the necessity of making the calculations as described above it is more convenient

to provide the watch or time-piece with a special dial, from which the bearing may be read off directly.

In connection with acoustic signalling apparatus the application of a chronometer provided with a dial graduated as a compass scale has been patented by W. A. Loth*; but this device is not applicable to a rotating beacon. For this purpose a stop-watch may be used provided with a dial somewhat similar in type to that proposed for use with the Telefunken Compass in 1912†. In this case the observations were made on the points of maximum signal strength, and the device did not come into widespread use owing probably to its limited accuracy and to the lack of uniformity of the time of rotation of the transmitter. A modern rotating wireless beacon can, however, be accurately controlled by a vibrating tuning fork, and its rotation is thus very uniform and can be set to make one revolution per minute to within a limit of about one-hundredth of a second.

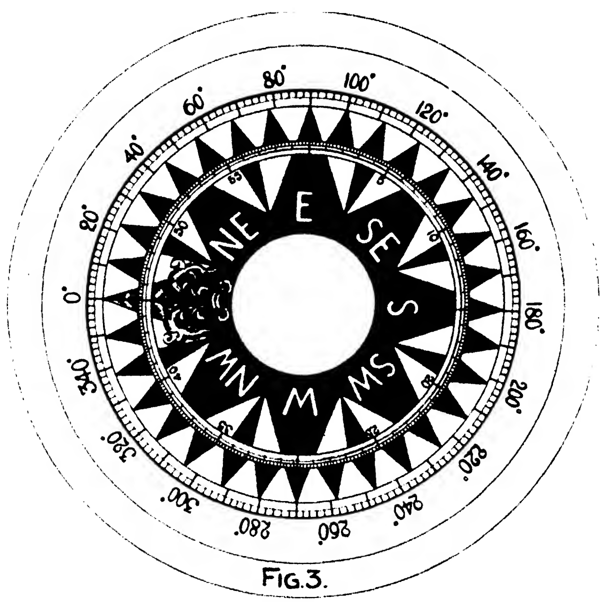


FIG. 3.

A dial is shown in Fig. 1 as being suitable for mounting on a watch whose index hand rotates once in sixty seconds, and for use with a modern rotating beacon making one revolution per minute. The outer scale is calibrated directly in degrees from 0° to 360°, the second scale is marked in points of the compass, while the innermost scale is marked off in seconds. It is evident that if the index hand of a time-piece provided with such a dial is started from the 0° or N. point when the beacon gives its characteristic N. signal, then when the received signal passes through its minimum intensity the position of the index hand will indicate directly the bearing of the transmitter from the receiver. If necessary the scales of the dial could be arranged so that either true or magnetic bearings can be read off as desired. In this case an adjustment would be necessary between the two scales, to allow for the magnetic scale to be set according to the magnetic variation at the place of observation. The photograph, Fig. 2, shows an ordinary sixty-seconds stop-watch provided with a dial similar to Fig. 1.

In certain cases where the receiver is situated directly North or South of the transmitter, the characteristic North signal would possibly not be heard owing to the passage of the signal intensity through its minimum. To allow for such conditions it is usual to arrange for

* British Patents 200,825/1923 and 222,541/1924.

† *Electrician*, **69**, 1912, p. 270.

the transmitter to send another characteristic signal corresponding to the East position. If a time-piece with a dial as in Fig. 1 is employed in such a case the same procedure may be followed, except that 90° must be added to the dial reading to obtain the correct bearing. On the other hand, a separate watch might of course be used, the dial of which is suitably engraved to permit of starting from the E point, as shown in Fig. 3. Alternatively the watch may be provided with the means for rotating the dial until the starting position of the index hand lies over the 90° or E point of the bearing scales.

Variations on the dial may be made to permit of its use with a beacon rotating at any other speed than once a minute. For example, for certain purposes it would be more convenient to employ a beacon which made one revolution in two minutes. In this case a dial of the type shown in Fig. 4 may be employed on a time-piece whose index hand rotates once a minute.

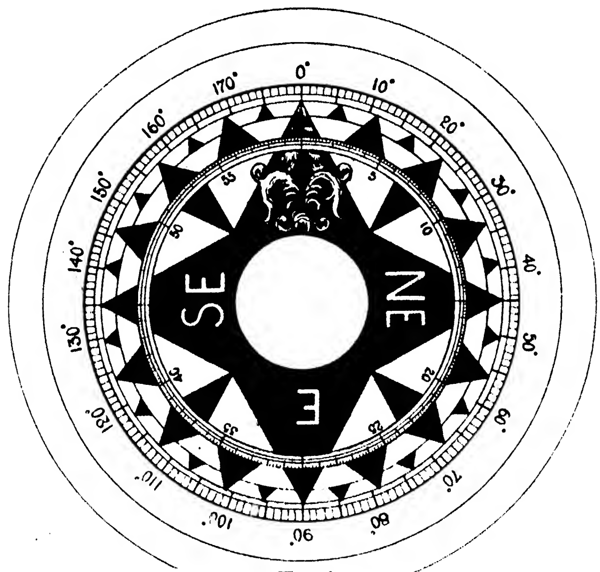


FIG. 4.

Considering that the important application of rotating wireless beacons is for navigation purposes, it is much more convenient to have the index dial marked out as a compass scale, with which the navigator is familiar, rather than as a time scale, since the time factor is but an intermediary step in the obtaining of a wireless bearing in this manner. Apart from this direct application the writer has found the use of this dial of very great assistance in explaining the employment of this system of wireless bearings to marine navigators*.

Chronographs provided with the type of dial described in this paper have been used in connection with the investigation of a rotating beacon transmitter carried out for the Radio Research Board, established under the Department of Scientific and Industrial Research†; but the application of the dial is not restricted to wireless beacons. It can equally well be applied, for example, to a sound signalling scheme, in which the direction is obtained from a time measurement of some rotating component.

* A paper describing the application of the beacon to marine navigation will shortly be published by The Institution of Electrical Engineers. (R. L. Smith-Rose and S. R. Chapman: "The Application of the Rotating Beacon Transmitter to Marine Navigation." *Journ. I.E.E.* 1928, vol. 28.)

† A report describing a comprehensive investigation on the performance of a rotating beacon transmitter is shortly to be published by H.M. Stationery Office (R. L. Smith-Rose and S. R. Chapman: "An Investigation of a Rotating Radio Beacon," Radio Research, Special Report, No. 6, 1928).

AN APPARATUS FOR THE DETERMINATION, IN SMALL VOLUMES OF FLUID, OF THE OSMOTIC PRESSURE OF COLLOIDS.

By E. B. VERNEY, M.A, M.B., M.R.C.P. (From the Department of Pharmacology, University College, London.)

[*MS. received, 22nd September*, 1927.]

ABSTRACT. A method is described based on that devised by Starling* and modified from those of Moore and Roaf†, Sörensen‡, Krogh§ and Govaerts|| by which the osmotic pressure of the colloids in blood plasma may be determined at various temperatures, under aseptic conditions, and in volumes of fluid as small as 1 c.c.

Introduction

In studying the mode of interchange of water and diffusible solutes across the wall of the capillary vessels which separate the blood plasma from the fluid in the tissue spaces, it is clearly important that determinations should be able to be made of the osmotic pressure of those plasma constituents to which the capillary wall is normally impermeable, viz. the proteins. In order that such determinations should be possible in the human subject it is essential that the method should necessitate the use of only small volumes of plasma. Further, if the measurements are to be made at room or body temperature the apparatus must be sterilisable and the whole technique carried out under strictly aseptic conditions.

In the past the membrane of the osmometer has usually been made of collodion or gelatine, and certain difficulties are encountered if membranes of uniform permeability are to be obtained. These difficulties have been overcome by Govaerts|| who has made use of discs cut from a sheet of "cellophane"¶ of uniform thickness. The disc is mounted in a brass capsule in such a manner as to separate the protein-containing fluid within the capsule from the protein free fluid in which the capsule is immersed. A hole in the upper surface of the capsule is plugged by a glass capillary tube, the lumen of which can be shut off from the atmosphere by the closure of a tap. After equilibrium has been attained between the solutions on either side of the membrane, the osmotic pressure of the non-diffusible constituents of the plasma is determined from the simple measurement of the pressure of the small volume of air confined in the capillary tube between the meniscus of the plasma and the tap, as was done by Krogh§.

Description of Apparatus

The apparatus is essentially that devised by Govaerts, but its disposition has been modified so as to make possible its immersion in a water thermostat. It consists of a brass capsule *A* (Fig. 1) the capacity of which is 1 c.c. This is threaded externally to accommodate the internally threaded brass ring *B*, and opens below through a hole 8·5 mm. in diameter. A thin perforated copper disc *C* is supported circumferentially in a groove cut in the upper and inner surfaces of *A*. Black rubber washers are placed in the positions shown at *D* and *E* and a disc of cellophane lies immediately below the copper disc *C* and is coextensive with

* Starling. *Journ. of Physiol.* **24** (1899) 317.
† Moore and Roaf. *Biochem. Journ.* **2** (1907) 34.
‡ Sörensen. *Compt. Rend. Lab. Carlsberg.* Vol. 12.
§ Krogh. *The Anatomy and Physiology of the Capillaries.* Yale University Press. 1924.
|| Govaerts. *Bull. de l'Acad. Roy. de Méd. de Belg.* **4** (1924) 161.
¶ Made by the Cellophane Company, 7 Bird Street, London, W. 1.

it. When *B* is screwed down into position the cellophane disc is held securely in contact with the washer *D* and effectively closes the capsule above. A glass capillary tube *F*, of 7 mm. external diameter, provided with a tap *G* and bent as shown in the figure, is held

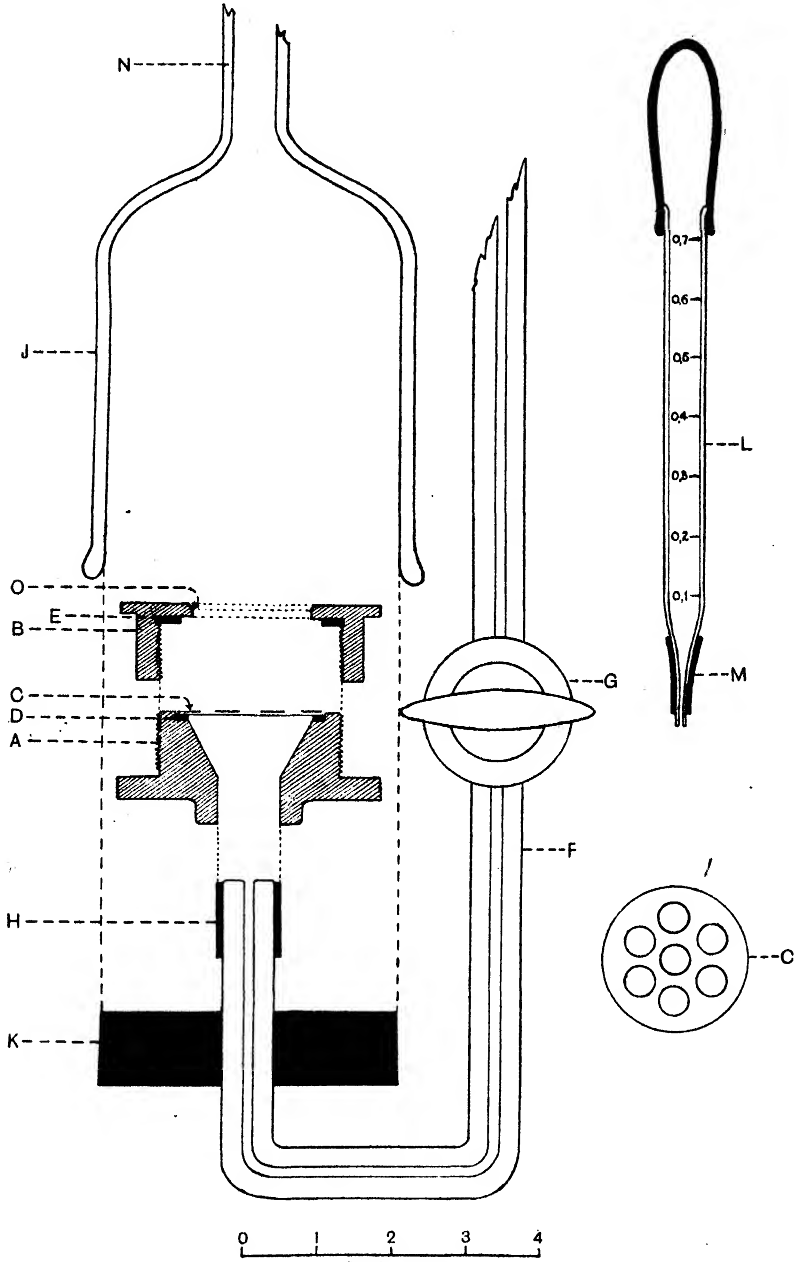


Fig. 1

securely in the hole in the base of *A* by means of a small length of rubber tubing *H*. The osmometer is covered with a glass cup *J* which fits on to a rubber bung *K* through which the shorter limb of the capillary tube passes.

The protein-containing fluid is placed in the capsule, and some passes up the capillary tube when the latter is pushed into position, the tap *G* being open during this process. The

outer non-protein-containing liquid (0·5 c.c. is sufficient), is placed in the hollow immediately above the cellophane, by means of a graduated pipette *L* provided with a teat, and having its point guarded by a rubber tube *M*. This last is to prevent the point of the pipette becoming contaminated bacterially when the pipette is being introduced through the glass tube *N* (4 cm. long) of the osmometer cup, this part of the apparatus not being sterilized.

Before use the brass capsule, copper disc, glass capillary tube, and the pipette *L*, are dry sterilized at 130° C. for one hour, and the rubber washers, cellophane discs and the solution which is to form the outer liquid autoclaved at $1\frac{1}{2}$ atmospheres for 45 min.

In order to prevent both the protein liquid and that against which it is dialysed from coming into contact with the brass and copper of the instrument, the inner surface of the

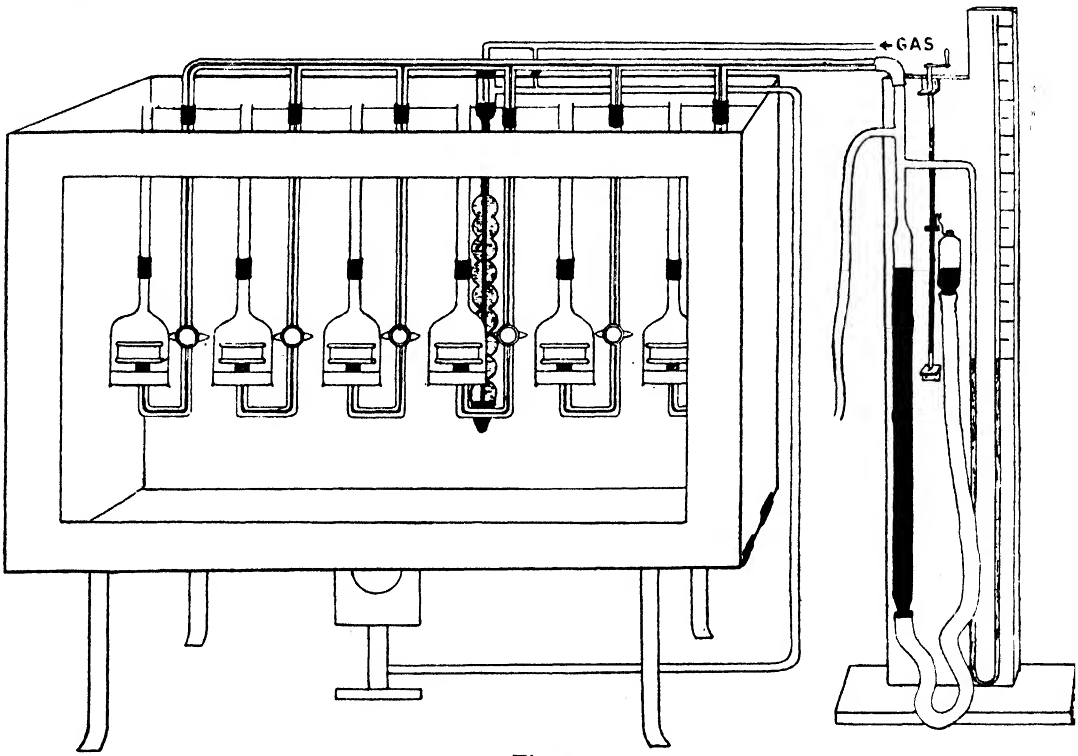


Fig. 2
(Reprinted from *Journ. Physiol.* Vol. 61, p. 323, 1927.)

capsule, the copper disc and the internal rim *O* of the brass ring *B* are coated with a thin film of sterile paraffin wax, before the component parts of the osmometer are assembled.

A glass extension tube is attached to the top of the osmometer cup *J* in order that the apparatus may be immersed in a thermostat tank. The latter is 2 ft. × 1 ft. × 1 ft. deep with a glass back and plate glass front. A tank of this size will accommodate six osmometers in a row. The ends of the long limbs of the capillary tube (15 cm. from the tap) may conveniently be connected by means of a capillary tree to a mercury reservoir with levelling tube and water manometer, as shown in Fig. 2.

After the osmometer has been set up the tap *G* is closed and the apparatus is left for 24 hrs. at constant temperature. It was found that with the cellophane used (thickness = 0·005 cm.) the osmotic pressure reached its final value within this time. To determine this value the meniscus in the capillary is observed through a microscope fitted with a 3 in. objective and micrometer eyepiece. On opening the tap *G* the meniscus rises, but can be brought back to its previous level by adjustment of the mercury levelling tube. When this level has been

reached the water manometer reading is taken. Then the true osmotic pressure of the non-diffusible constituents of the inner liquid is given by the equation

$$P = P_1 + H_1\rho_1 - H_2\rho_2 - C;$$

where P = true osmotic pressure in cm. H_2O.
P_1 = manometer reading in cm. H_2O.
H_1 = height of meniscus above level of membrane in cm.
H_2 = height of outer liquid above membrane in cm.
ρ_1 = density of inner liquid.
ρ_2 = density of outer liquid.
C = capillarity of tube in cm. H_2O.

The apparatus has been employed in the measurement of pressures ranging between 6 and 50 cm. H_2O.

The average value of the probable error of a single observation within this range is 0·5 cm. H_2O. Details as to the technique of the method and the precautions which must be taken in its use are given elsewhere*.

A SIMPLE AIR THERMOSTAT. By L. G. CARPENTER, B.A., B.Sc., and L. G. STOODLEY, B.Sc. University College, Southampton.

[*MS. received, 6th December*, 1927.]

ABSTRACT. In this note a simple form of air thermostat is described, and a formula for the sensitivity is given.

Introduction

Thermostats depending on the expansion of air have been described by several previous workers, notably by Houghton and Hanson†, who developed an instrument for use at moderate and high temperatures. The object of the present note is to describe a simple form of air thermostat, and to call attention to the conditions of design for optimum sensitivity.

It is not claimed that the formula presented enables a prediction of the sensitivity to be made; it is intended merely to serve as a guide in designing the instrument so as to attain the maximum sensitivity. The main points of interest are

(1) The effect of inclining the limbs of the mercury-filled U-tube, and

(2) The fact that, under suitable conditions, the sensitivity is practically independent of the size of the regulator bulb.

Description of Instrument

The thermostat, of which a photograph is reproduced in Fig. 1, consists of a U-shaped tube of glass, containing mercury, the right-hand limb A being composed of a 1 mm. capillary, and the remainder of tubing of 3·5 mm. internal diameter. A small piece of 3·5 mm. tube is also sealed to the top of the capillary in order to permit of the fastening of the adjusting screw S and terminal. The contact is a piece of iron wire soldered to the adjusting screw, the joint being protected from mercurial corrosion by shellac varnish. Connection to the mercury is made by means of a platinum wire sealed through the end of the side-limb B in the horizontal portion of the U-tube, the barrel connector cemented

* Verney. *Journ. of Physiol.* **61** (1926) 319.
† *J. Inst. Met.* **14** (1915) 145–153; **18** (1917) 173–186.

to the end of the tube being used as a terminal. The left-hand limb is connected by a rubber tube R to the control bulb, a tap T being provided for purposes of adjustment.

The whole is mounted by copper straps and rubber cushions on a board, the angle of inclination of which can be varied by means of the hinged joint and "Shadbolt stay" D, shown in the photograph. The lower board is weighted with lead to prevent any possibility of the instrument overturning. The completion of the circuit through the mercury-iron contact energizes a relay which opens the main heating circuit until contact is re-established. The relay is operated by a 2 volt accumulator, and takes about 0·2 ampere. Sparking is minimized by a 2 microfarad condenser C connected across the break. Scrupulous cleanliness of both mercury and glass is necessary to ensure reliability and sensitivity.

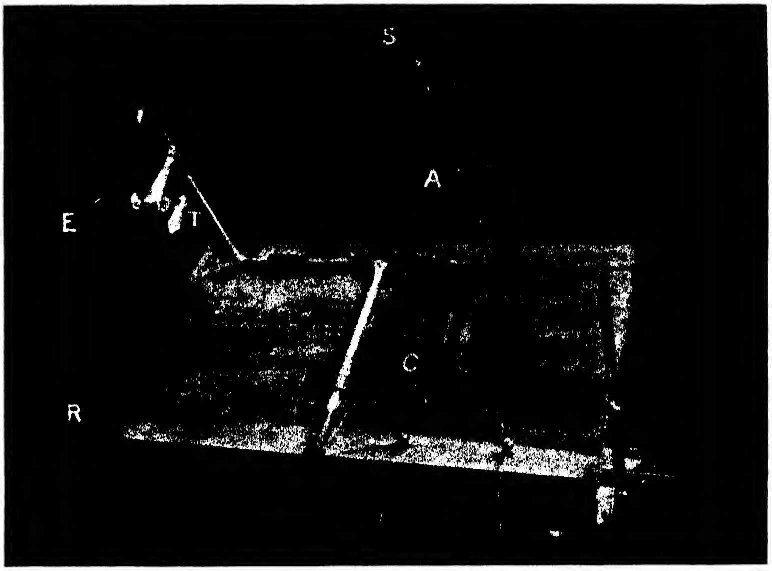


Fig. 1

Let V_1 = volume of air in the regulator bulb at bath temperature T_1 abs.

V_2 = volume of air in the connecting tube, supposed to be at air temperature T_2 abs.

h = "pressure" in regulator bulb in cms. of mercury.

a = cross-section of capillary limb, and λ the sine of the angle at which it is inclined to the horizontal.

b and λ' = the corresponding quantities for the other limb.

l = length of mercury thread in the capillary limb, measured from some arbitrary point.

Then, by a simple application of the laws of Boyle and Charles, T_2 being assumed constant, the following equation may be deduced:

$$\frac{dl}{dT_1} = \frac{1}{T_1}\left\{\frac{1}{\frac{a}{V_1}\frac{T_1}{T_2} + \left(1 + \frac{V_2}{V_1}\frac{T_1}{T_2}\right)\left(\lambda + \lambda'\frac{a}{b}\right)\frac{1}{h}}\right\} \qquad \text{......(1).}$$

In the instrument described, $\lambda' = \lambda$, and the equation reduces to:

$$\frac{dl}{dT_1} = \frac{1}{T_1}\left\{\frac{1}{\frac{a}{V_1}\frac{T_1}{T_2} + \left(1 + \frac{V_2}{V_1}\frac{T_1}{T_2}\right)\left(1 + \frac{a}{b}\right)\frac{\lambda}{h}}\right\} \qquad \text{......(2).}$$

For the dimensions given below, the $\frac{a}{V_1}\frac{T_1}{T_2}$ term is small in comparison with the second term of the denominator, so that the travel of mercury per degree rise in bath temperature, which is the factor that primarily determines the sensitivity, depends on the second term of the denominator only. The second term, however, only involves V_1 in the factor $\left(1 + \frac{V_2}{V_1}\frac{T_1}{T_2}\right)$ which is approximately independent of V_1 for values of V_2 small compared with V_1. Hence, by choosing suitable dimensions, the sensitivity of the thermostat can be made practically independent of V_1. To obtain maximum sensitivity the following conditions must be fulfilled:

(*a*) $\left(1 + \frac{V_2}{V_1}\frac{T_1}{T_2}\right)$ must be a minimum. V_2 can easily be made of the order of 1 c.c. for connecting tubing of length 1 metre. Hence for a regulator bulb of only 10 c.c. capacity, and with (say) $T_1 = 363$, $T_2 = 283$, the value of $\left(1 + \frac{V_2}{V_1}\frac{T_1}{T_2}\right)$ is within 13 per cent. of its theoretical minimum.

(*b*) $\frac{a}{b}$ must be small. A reasonably large value of a must be chosen, owing to surface tension effects, about 1 mm. diameter being the smallest permissible, and b fixed accordingly. In the instrument described

$$\frac{a}{b} = \left(\frac{0{\cdot}10}{0{\cdot}35}\right)^2 = 0{\cdot}08.$$

(*c*) λ must be as small as possible. In practice, values below about $\frac{1}{2}$ cannot be used, otherwise, with decrease of gravitational control, the effects of surface tension and "stiction" become very marked, and the action uncertain.

In use, the bath is heated to within 1° C. of the required temperature with the tap T open to the air. Air is blown in through the tube E provided, until the mercury is within $\frac{1}{2}$ mm. of the contact. The tap is then closed, final adjustment being made with the adjusting screw.

The temperature constancy depends not only on the design of the thermostat itself, but also on the efficiency of the stirring, and on the position of the heating coil in the bath. In fact, for best results the coil should be wound on the surface of the regulator bulb itself. In this case, of course, the time average of the temperature of the bulb will exceed the time average of the temperature of the bath. In the formula, however, the effect of thermal lag is neglected; we confine ourselves to a consideration of the geometrical design only.

Experimental Results

(*a*) *Experiments to determine the sensitivity of temperature control*

The bath used was a glass beaker of 1000 c.c. capacity, filled with water. Stirring was effected by a vertical motor-driven paddle. Using a heating input of 32 watts, the bath could be maintained at a temperature of 22°–24° C., about 10° above atmosphere, with less variation than could be detected on a thermometer graduated in tenths of a degree, certainly within 0·02° C. A complete cycle of operations of the relay occupied only 4 to 10 seconds, the actual period depending on λ. The bath could also be maintained at a temperature of 90° C. with similar accuracy, the heating input being increased to about 400 watts.

(b) Experiments to verify the formula

Using the same bath as before, the shift of mercury in the capillary limb due to a given rise in temperature was observed, and the result compared with the calculated value of $\frac{dl}{dT_1}$ obtained from equation (2).

λ	Observed mm./deg.	Calculated mm./deg.
1·00	1·93	1·96
0·86	2·61	2·21
0·45	4·00	4·20
0·29	4·17	6·41

Theory and experiment are in fair agreement except in the case of $\lambda = 0{\cdot}29$, where the limbs of the U-tube were nearly horizontal, showing that surface tension and "stiction" are here having considerable influence on the action.

The thermostat, as described, is sensitive to changes of atmospheric pressure, but this effect may be eliminated by connecting the limb carrying the contact to a large bulb maintained at constant temperature. This may be conveniently done by surrounding the bulb with ice.

Our thanks are due to Professor Stansfield, in whose laboratory these experiments were carried out.

NEW INSTRUMENTS

IMPROVED DUDDELL OSCILLOGRAPH OUTFIT

ABSTRACT. A compact portable form of Duddell Oscillograph is described which has many applications in connection with electrical engineering practice and which is also adapted for teaching and demonstration purposes. Typical oscillograms are reproduced, as illustrating some applications of the apparatus.

It is now generally felt that the oscillograph is an almost indispensable aid to the investigation of transient and rapidly varying electrical phenomena, and the increasing use of alternating currents has stimulated the demand for a compact portable instrument which may be easily adapted for various tests. Such an instrument should of necessity be easy to operate and sufficiently robust in construction to withstand ordinary workshop conditions.

The outfit illustrated in Fig. 1 has been developed by the Cambridge Instrument Company, Ltd., to meet the demand for an instrument of this type which may be used on circuits up to 100,000 volts. The outstanding advantage of the design, as compared with that of earlier models, lies in the fact that simultaneous records may be obtained from three vibrators which may be any combination of the electromagnetic and the electrostatic types—only one camera and one source of light being required. The source of light is an ordinary 6-volt metal filament lamp to which a greatly abnormal voltage is applied for a fraction of a second during the time of exposure. The intense light thus obtained passes through an optical system which ensures that a separate beam is focussed on each vibrating mirror. The reflected beams pass through a cylindrical lens, thereby reducing the images to bright spots of light on the photographic paper, or film, which is traversed in a vertical plane at right angles to the plane of the vibrating beams. The

complete outfit is enclosed in a compact metal case, which is approximately 90 cm. in length, 31 cm. in width and 36 cm. high. The oscillograph may be used to study the

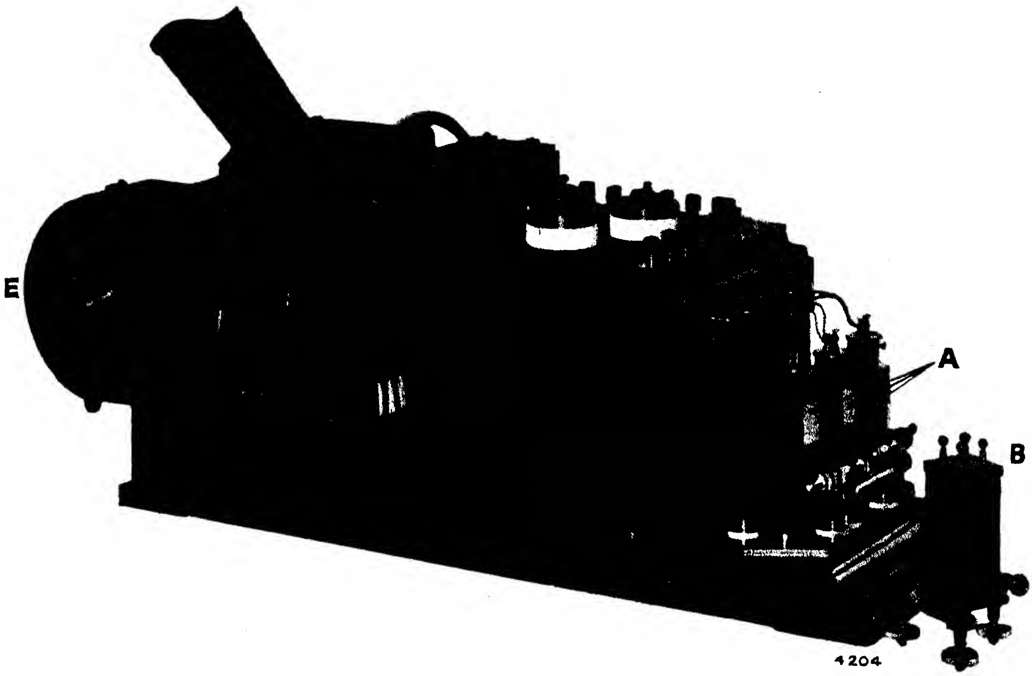


Fig. 1

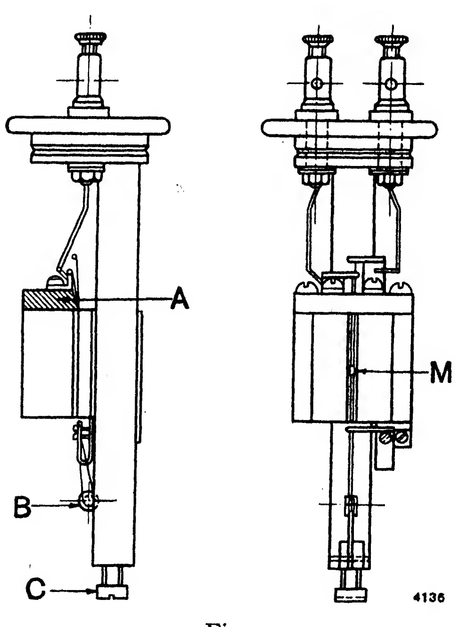


Fig. 2

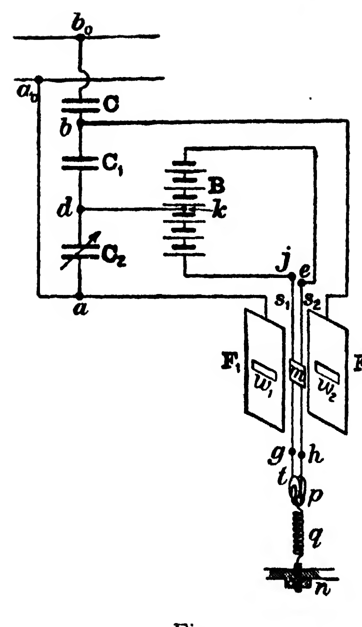


Fig. 3

recurrent or transient phenomena of almost any commercial or laboratory circuit. It is normally suitable for use on commercial circuits up to 600 volts.

The electromagnetic vibrator is similar in design, but smaller in dimensions, than the original Duddell pattern. It is shown diagrammatically in Fig. 2. Each vibrator is mounted

in a separate oil bath, placed in the gap between the pole pieces of a permanent magnet. Provision is made for adjusting the position of the vibrator relative to the base and for levelling the complete unit. A lens is recessed into the oil bath so as to be as near as possible to the mirror. The natural periodic time of the vibrating system is about 0·0003 second when undamped, that is, without oil in the damping chamber; when damped, a direct current of 60 milliamperes results in a deflection of 2 cm. on a scale at a distance of 60 cm. The maximum R.M.S. current is 0·1 ampere.

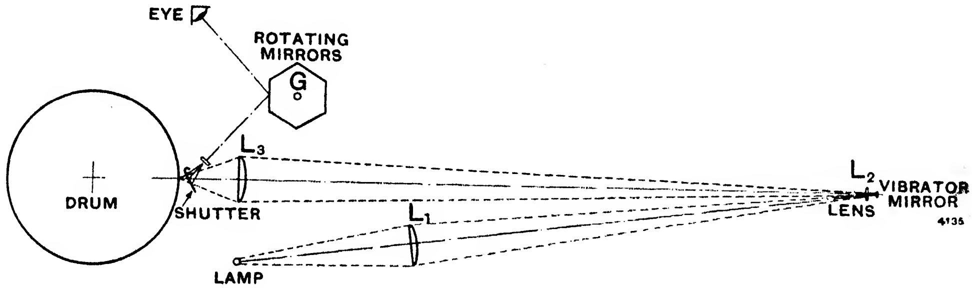


Fig. 4

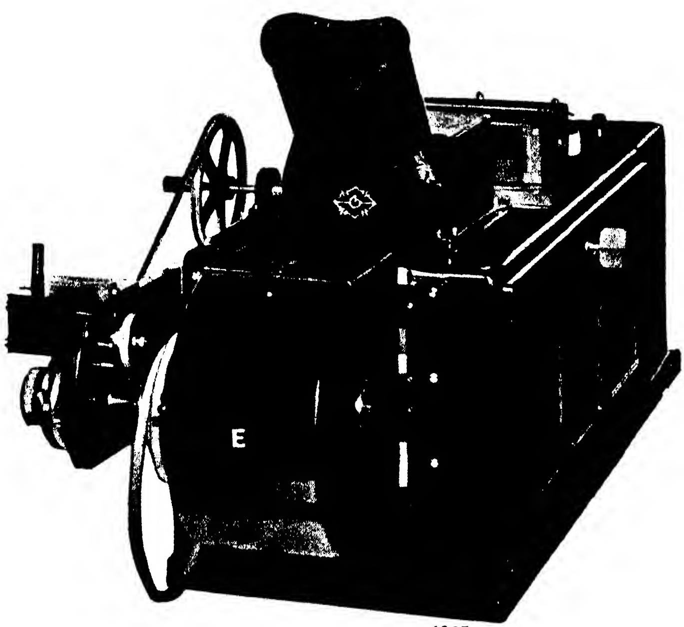


Fig. 5

The electrostatic vibrator is a modification of Professor Ho's original design*. The electrical arrangement of the circuit is shown in the diagram in Fig. 3. The magnetic field of the electromagnetic vibrator is replaced by an electrostatic field which is produced by applying the alternating pressure to the two metal plates, F_1 and F_2. If the pressure exceeds about 2500 volts, the oscillograph is connected in series with a condenser C which reduces the pressure to a suitable value at the oscillograph terminals a, b. Two bronze strips s_1, s_2, are stretched between the plates F_1, F_2, so that the strips are parallel to one another and to the plates. The strips are electrically insulated from one another by being joined at

* See *Proc. Phys. Soc.* **26** (1913) 16.

g and h to a silk thread which passes over an ivory pulley p; to this pulley is attached a spring q which keeps the strips in a state of tension. The strips are charged with a definite potential by connecting the terminals e, j, to a dry battery B mounted on an insulated stand. To make the potential of the strips definite in relation to the field plates, two condensers C_1 and C_2 in series are connected to the points a, b across the field plates. The electrical centre k of the battery is connected to the point d between these condensers. If the condensers C_1 and C_2 are equal, and the strips are midway between the plates, the amplitude of the vibrations of the strips will be equal when an alternating pressure is applied to the terminals of the oscillograph. A small mirror m which is bridged across the strips will therefore be deflected (since the strips, owing to their opposite electrification,

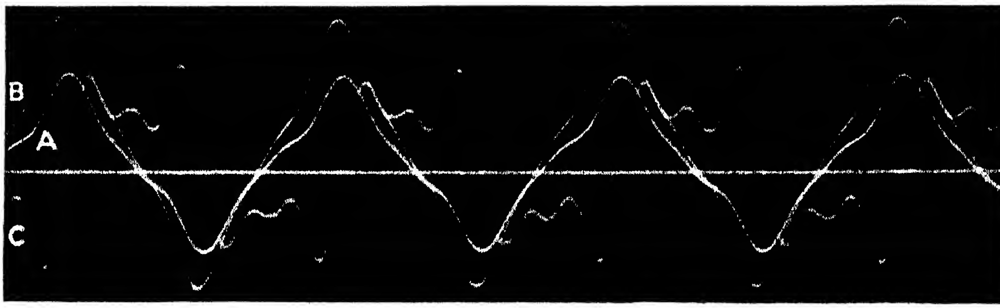


Fig. 6

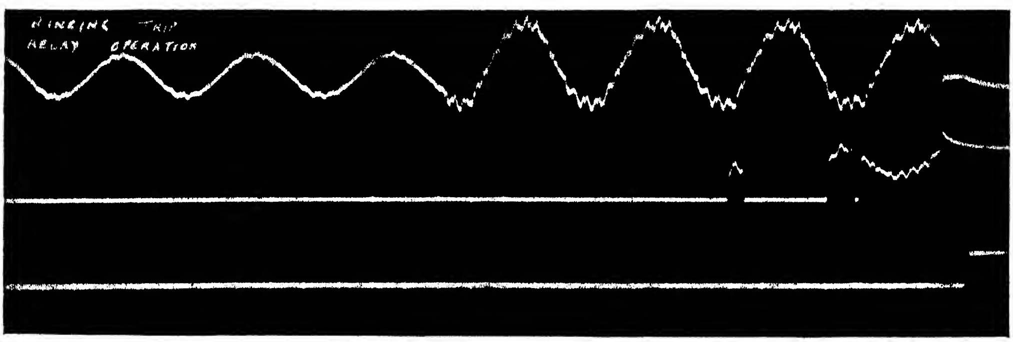


Fig. 7

will move in opposite directions in the field). This deflection is observed by focussing a beam of light on the mirror, the incident and reflected beams passing through a small opening w_1 in plate F_1. An exactly similar opening w_2 is cut in plate F_2 in order to maintain symmetry in the electric field. In practice it is found desirable to provide an electrical adjustment by making one of the condensers, namely C_2, variable. The periodic time of the strips undamped is about 0·0003 second; the amplitude of vibration (that is, the amplitude of the half wave) is about 6·2 millimetres per thousand volts at a scale distance of 60 cm., with a potential of 400 volts D.C. between the strips. An electrostatic vibrator in its oil bath is shown at B in Fig. 1; the unit is approximately of the same dimensions and is interchangeable with the electromagnetic units shown at A.

The arrangement of the optical system is shown diagrammatically in Fig. 4. The light from the lamp passes through three plano-convex lenses L_1 (one of which only is shown in the diagram) and is thereby focussed on to the vibrating mirrors by the vibrator lenses L_2.

The reflected beams pass through the cylindrical lens L_3 which reduces them to bright spots of light in the plane of the photographic paper or film. When the camera shutter is closed, the three spots of light so formed are reflected from the back of the shutter and pass through a semi-transparent celluloid screen on to the hexagonal viewing mirrors G. The latter are rotated about a horizontal axis in the initial plane of vibration of the beams, the necessary power being obtained from the camera-driving motor. Any stray light is cut off by a screen fitted above the focussing lens L_3. A zero mirror, which is illuminated by the central beam, provides a datum line for both visual and photographic observations. The camera, shown at E in Figs. 1 and 5 is of the simple drum pattern; it slides into guide bars at one end of the dark box. It is loaded in a dark room, the photographic paper (or film) being wrapped round the drum and held in position by means of a novel form of clamp. The drum is rotated by a variable speed direct current motor, the range of paper (or film) speed being from about 40 to 600 centimetres per second.

By fitting a series of cams to the camera drum spindle the whole length (48 cm.) of paper (or film) may be utilised in either one, two or four exposures, as desired. A mechanical device ensures that the interval of time which elapses between the extra voltage being applied to the lamp and the camera shutter being opened enables the lamp to reach its maximum brilliancy before a record is taken. The necessary switches and terminals are mounted on a panel on the top of the case.

Typical oscillograms are reproduced, approximately three-quarters actual size, in Figs. 6 and 7. In Fig. 6, records A and B show E.M.F. and current wave forms respectively, which were obtained on alternating current mains (75 volts, 50 cycles) while record C was obtained by introducing a condenser (1·7 microfarads) in series with the third vibrator. The curves in Fig. 7 (which is reproduced by courtesy of the General Post Office) show the operation of automatic telephone relays. The vertical lines are produced by interrupting the focussed beam of light every 0·01 second by a time marking device.

When the oscillograph is to be used in investigations which last a considerable time, the drum camera may be replaced by a camera using ordinary standard cinematograph film. Records up to 30 metres in length may then be obtained.

NEW SPECTROSCOPES AND SPECTROMETERS

MESSRS R. AND J. BECK, LTD., of 69, Mortimer Street, W. 1, send the following particulars of their new spectroscopes and spectrometers:

We have for many years manufactured a series of spectroscopes in which are employed diffraction gratings in place of a train of prisms. The gratings are replicas, cast from an original Rowland's grating, having 14,950 lines per inch, and give the advantages as to dispersion which are characteristic of the grating type of instrument.

We have recently added several new patterns to our series:

The "Minimum" Pocket Spectroscope (Fig. 1), which is an instrument of extremely small size, being 2 inches long and $\frac{7}{16}$ inch diameter, has been used for many years for medical and chemical work, and we have now made a small spectroscope on the same principle but with the addition of an adjustable slit. This has necessarily increased the size, but it is still contained in a small case measuring $2\frac{7}{8}$ inches by $1\frac{5}{8}$ inches. This spectroscope is "direct vision" and has a dispersion of about 20°. The adjustable slit greatly adds to its utility. The instrument is also made with a comparison prism, so that the spectrum being examined can be compared with that of a standard or other light source.

We have also produced a spectroscope employing the reversion system of reading, on the principle suggested by Professor H. Hartridge, F.R.S. (Fig. 2). Two spectra are produced side by side which are reversed in the direction of their colours. Upon turning the milled head, which is divided into 100 arbitrary divisions, both spectra move in the

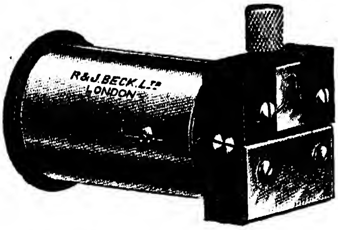
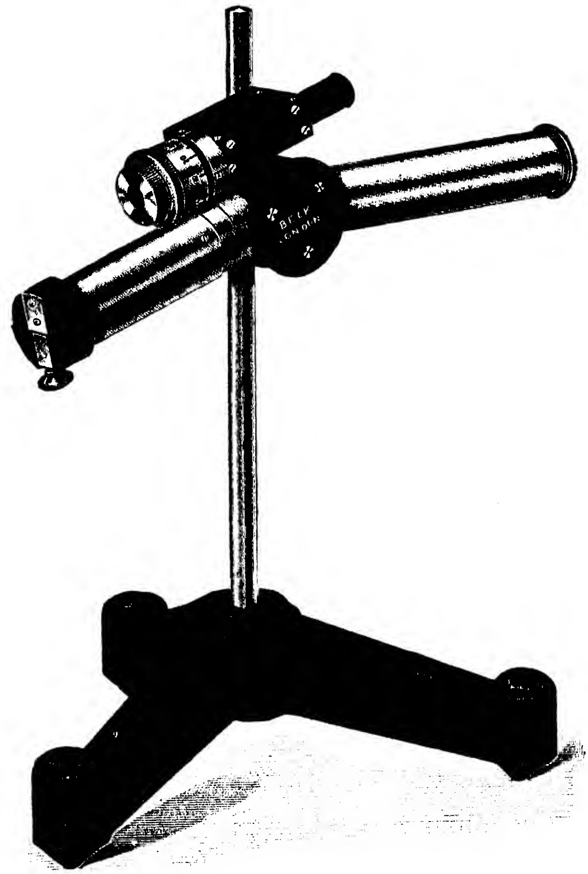


Fig. 1



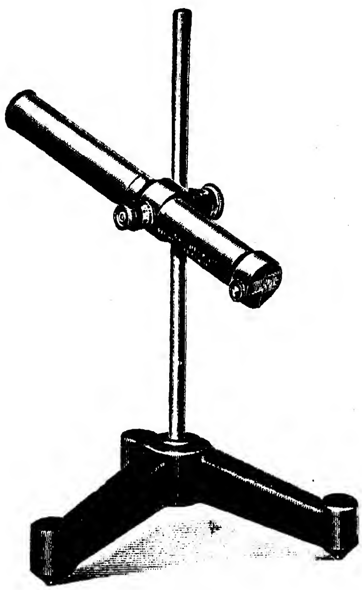


Fig. 2

Fig. 3

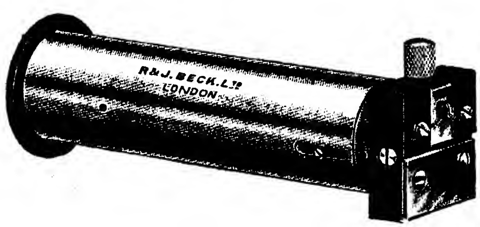


Fig. 4

field but in opposite directions. The reading is obtained by setting a particular line in one spectrum against the same line in the other spectrum. This method not only gives twice the accuracy of setting, but the positions of indistinct absorption bands can be taken with considerable accuracy. The instrument itself is direct vision and is 4 inches long and 1¼ inches diameter.

We have also re-designed our wave-length model spectroscope in which the readings are made direct in wave-lengths (Fig. 3). A replica diffraction grating is employed, mounted

in a box in the centre of the instrument. Fixed to this is a collimator with an adjustable slit. Upon this box also is hinged a telescope, its relative angle with the collimator being varied by means of a micrometer screw which moves the telescope on a sine motion. The position of lines in the spectrum as they travel across the cross-line in the eyepiece can be read direct into wave-lengths. The milled head has 100 divisions, each division representing 10 A.U.

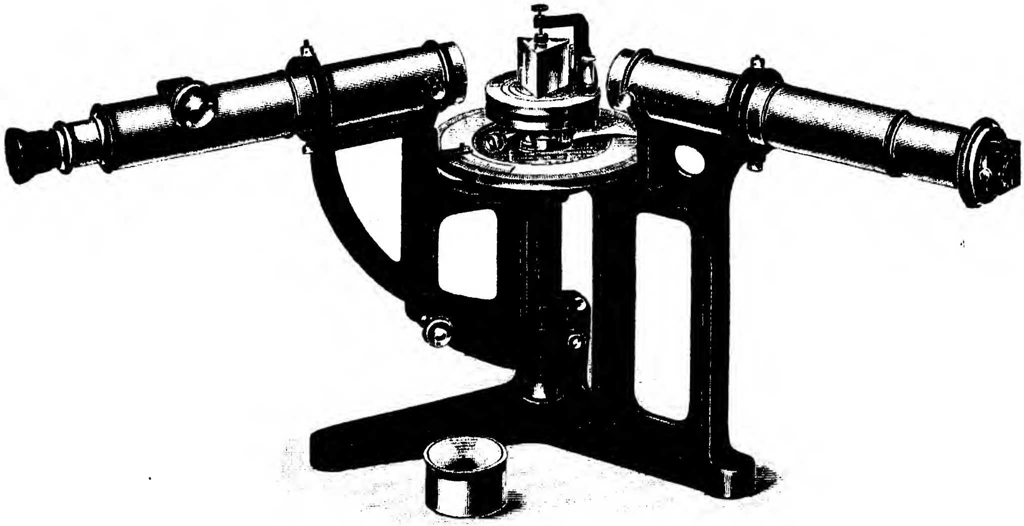


Fig. 5

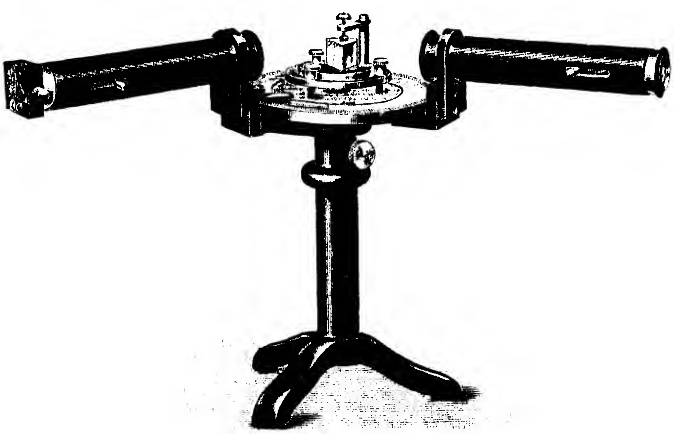


Fig. 6

In addition to those utilising replica gratings we have produced a small direct vision spectroscope (Fig. 4), employing a train of five prisms. It has a dispersion of 10° and has an adjustable slit. This type of spectroscope gives great brilliancy in the spectrum.

A new design has been introduced in the "Girder" spectrometer, which has been constructed with a view to increasing the rigidity beyond that given in the usual type of instrument made for laboratory use (Fig. 5). The stand, as may be seen from the illustration, consists of a main casting with three feet having a very large spread. Cast solid with this is a framework supporting the collimator, and a centre pillar which carries a 6-inch divided circle. Upon the centre pillar and rotating by means of long bearings is a framework upon

which the telescope is fitted. The long bearings upon which this is fitted ensure a perfectly smooth motion and obviate any shake or lack of rigidity in the telescopic portion of the instrument. The other parts of the spectrometer are similar to those usually supplied on such models and can be seen from the illustration.

A smaller and simplified spectrometer has also been produced, the general features of which can be seen from the illustration (Fig. 6). This has a 4 inch divided circle, and is a simple though satisfactory instrument at a moderate cost.

CORRESPONDENCE

UNIVERSAL LONG-WAVE RADIO INTENSITY MEASURING SET

I REGRET that a few errors occur in my paper "A new Universal Long-Wave Radio Intensity Measuring Set" published in the January number of the *Journal*, and I should be much obliged if you would publish the following corrections:

(1) Page 4, fig. 4. There should be no connection between the grid of the first valve and the negative battery lead, and the fixed condenser shown next to the crystal should be on the other side of the choke coil, between this and the anode of the last valve.

(2) Page 6, line 6: for "effect" read "effective."
Page 6, line 11: for "hC_2" read "hC_1."

J. HOLLINGWORTH.

RADIO RESEARCH STATION,
DITTON PARK,
LANGLEY, BUCKS.

REVIEWS

In a Persian Oil Field. A study in Scientific and Industrial Development. By J. W. WILLIAMSON, B.Sc. London: Ernest Benn Ltd. Pp. 190. Price 7*s*. 6*d*. net.

This book, by the Secretary of the British Scientific Instrument Research Association is, as the author frankly states, an appreciation of the work of the Anglo-Persian Oil Company. Its object is to show in outline "the extent to which the Anglo-Persian Oil Company has applied and is applying, especially in Persia, scientific knowledge and scientific methods in the oil industry; and also to describe...some of the industrial, educational and social developments that have arisen... as natural outgrowths of the Company's work." It is the outcome of a visit to Persia, of about a month's duration, made at the invitation of the Chairman of the Company.

Mr Williamson has given a very readable account of his observations. The early chapters deal with the stages in the work which is completed when the refined oil is shipped to Europe and placed upon the market. An account is given of the methods of finding the oil, including the geological and topographical survey work; the geophysical methods, including the use of the Eötvös Torsion Balance, for supplementing the geological data; and the electrical, magnetic and seismic observations which have been used, with more or less success, to assist the main purpose of locating the oil and determining suitable positions in which to sink new wells.

The two principal systems of drilling are described, the cable tool or percussion system, and the rotary system; and an account follows of the engineering work at the head of a new well when it is brought into action. Two interesting chapters follow, one on the problem of utilization of the gas, great quantities of which are given off with the oil, and a large part of which is still burned to waste in huge flares which burn day and night and light the country round; and the other on the maintenance of the pipe line, by means of which the crude oil is conveyed from the principal producing area to the refinery at Abadan, 135 miles away.

A brief description of the refining process and of the extraction of by-products is given, and of the research organizations of the Company, in Persia and in England, carrying out investigations in connection with the refining of the crude oil and dealing with innumerable problems directly or indirectly related to the utilization of the petrol and heavier fuel oils and other products.

The first part of the book, while it gives a good idea of the range of scientific work involved in oil production, leaves an impression of superficiality which is probably unavoidable in an attempt to deal with a technical subject briefly and in a readable manner. Part II describes the social and educational activities which are the outcome of the industrial operations in Persia. The employment of Persian labour on a large scale, drawn from a people entirely unaccustomed to industrial conditions, has extended the Company's activities far beyond the immediate purpose of oil production, and several chapters describe the organization for the education of young Persians and their subsequent training for employment in the Company's workshops; and also the measures in relation to medical attention, health, housing and supplies which the primitive conditions and undeveloped state of the country have made necessary.

The book is well printed and contains a number of illustrations, but would be improved by the inclusion of a better map or maps. The important point of Dar-i-Khazineh, for example, frequently referred to in the text, is not shown on the sketch map given. T. M.

Penrose's Annual (vol. XXX, 1928). Edited by WILLIAM GAMBLE, F.R.P.S., F.O.S. London: Percy Lund, Humphries and Co., Ltd. Price 8*s*. net.

This volume gives an excellent idea of the progress of pictorial reproduction. It contains numerous fine examples of photo-mechanical engraving and printing. Recent developments are well summarized in the editor's foreword, and in technical articles by well known authorities on the graphic arts. H. M. C.

CATALOGUES

Standard Catalogue of Scientific Apparatus. (1928.) Vol. I: Chemistry. Baird and Tatlock (London) Ltd. Pp. 1142: illustrated.

This catalogue is the first volume of a comprehensive series to be issued by Messrs Baird and Tatlock (London) Ltd., illustrating apparatus and materials used in Chemistry, Physiology, Biological Sciences and Physics, and is well arranged into sections and subsections dealing with the various branches of pure and applied chemistry.

Easy reference is facilitated by a thumb index to the various sections. Since the last edition in 1923 it has increased in size from 954 to 1142 pages, and includes much new and interesting apparatus not described in the previous edition: the large number of these additions makes it impossible to review them completely within the narrow limits of this notice. It is proposed therefore to draw attention to a very limited number of the more interesting additions.

Section 1. Laboratory fittings.

Benches for housing microscopic and photomicrographic apparatus.

Section 2. General equipment.

Eötvös torsion balance for the location of minerals.

Sharples Super-centrifuge for the continuous or discontinuous separation of suspensions or emulsions into their phases.

Catterson-Smith electric resistance furnaces, heated by radiation from carborundum rods, giving a maximum temperature of 1300° C.

Hele-Shaw stream-line filter for the filtration of liquids by "edge filtration" through a pack of annular discs of paper.

Kaye-Backhurst annular all-metal vacuum pump, a development of the Langmuir condensation pump, for the production of high vacua of the order of ·00001 mm. Hg.

Hyvac two-stage rotary oil pump, for the production of a vacuum of ·001 mm. Hg. without the aid of a backing pump.

Section 3. Chemical apparatus.

British made glassware of Pyrex, Monax, and Chance brands.

Apparatus for the determination of Carbon, Hydrogen, and Nitrogen by the micro-analytical methods of Pregl and Dubsky.

Section 4. Physical chemistry.

Hurrell Homogeniser, a colloid mill for the preparation of stable emulsions and suspensions.

Boys gas calorimeter, for the determination of the calorific value of coal gas, as prescribed by the Gas Referees, 1924.

Section 5. Industrial chemistry.

Vickers hardness tester, for the measurement of Brinell hardness by indentation with a pyramidal diamond point. The load is applied in an automatic manner which eliminates all personal error.

Gray-King apparatus for the carbonization assay of coal, as designed and used at H.M. Fuel Research Station, Greenwich.

Metro gas circulator, designed by Messrs Pearson and Thomas of the South Metropolitan Gas Company. A stream of gas is pumped by means of an oscillating column of mercury (in a U-tube), the oscillations being maintained by connecting one limb of the U-tube to a heated bulb, which acts on the principle of the hot air engine.

Deeley friction machine, for the measurement of the "oiliness" or coefficient of boundary friction of lubricating oils.

The volume is completed by the addition of a selected bibliography, an exhaustive list of chemicals and reagents, and a good index, which is cross-indexed with the remaining three volumes of the series.

R. C. G.

NOTICES

BUILDING SCIENCE ABSTRACTS

A NEW monthly publication of interest to those concerned in building construction and allied subjects is to be issued by H.M. Stationery Office. Its purpose is to provide, for the Building Industry, up-to-date summaries of the latest developments in the science and practice of building. Such a service is already provided in other branches of applied science, and the Department of Scientific and Industrial Research has now decided to prepare for general circulation BUILDING SCIENCE ABSTRACTS. This has become possible partly as a result of generous support promised by the Institute of Builders.

Over 100 different scientific and technical periodicals are being drawn upon regularly in the preparation of the abstracts, which are classified under the following headings: Stone, mineral earths, clay and ceramics; Lime, plaster and chemical compositions in general; Cement and concrete; Metal; Organic building materials; Paint and varnish; Materials in general, their properties and testing; Elements of structures; Housing and domestic engineering; Specialized construction.

Publication will be monthly except in August. The subscription rate for the series of eleven monthly issues (including one double number) has been fixed at 10*s*. post free. Single copies are available, price 9*d*. each (post free, 10*d*.).

WE are informed that BAKELITE LIMITED is the new name of The Damard Lacquer Co. Ltd. and Mouldensite Limited, who, as the result of a scheme of amalgamation, have joined forces. The head offices are at 68, Victoria Street, S.W. 1, and the works, as hitherto, at Birmingham and Darley Dale. The arrangement also provides for "Redmanol" materials to be supplied by Bakelite Limited.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V — APRIL, 1928 — NO. 4

PRECISION METHODS IN RADIOACTIVITY.

BY L. BASTINGS, M.SC., B.A. The University, Durham.

[*MS. received, October 29th, 1927.*]

ABSTRACT. The simplest type of insensitive gold-leaf electroscope, as used in radioactive work, is critically and experimentally investigated with a view to increasing the accuracy of measurements made with this instrument. Results are quoted, showing a consistency of the order of 1 in 1000; and highly accurate comparisons are shown to be possible between radioactive sources of widely differing magnitudes.

THE gold-leaf electroscope has long been the instrument most generally employed in comparisons of the activity of radioactive sources, and in determinations of many of the radioactive constants. In the simplest form of the instrument, due largely to the pioneer work of C. T. R. Wilson*, and applied first to radioactive measurements by Rutherford†, the leaf system is enclosed in the ionization chamber, without any auxiliary electrode; and a potential of some hundreds of volts is set up between this and the earthed case by charging the leaf electrostatically. Such instruments usually have a cubical shape of about a litre in volume, and a capacity of between one and two electrostatic units; and when viewed with a telemicroscope and eyepiece scale of 100 divisions to the cm., have a sensitivity of the order of 1 division per volt.

The accuracy usually expected of radioactive measurements in general, and of electroscope measurements in particular, is of the order of 1 in 200 to 300. Thus Rutherford and Chadwick‡ say: "With a well-constructed electroscope, it is possible to compare approximately equal quantities of radium with a probable error of not more than $\frac{1}{2}$ to $\frac{1}{3}$ per cent.," while Makower and Geiger's§ verdict is that "the sensitiveness of an electroscope is very great, and with care measurements can be made with an accuracy of 0·5 per cent." Instruments capable of even this accuracy deserve to be described as electrometers, rather than electroscopes; and in what follows this term will be employed.

The present paper discusses the various factors that control the accuracy of this simple type of electrometer, and summarizes the results of improvements tending to increase this accuracy considerably.

* Wilson, *Proc. Roy. Soc.* **68** (1901) 151; **69** (1901) 277; *Proc. Camb. Phil. Soc.* **11** (1901) 32.

† Rutherford, *Phil. Mag.* **5** (1903) 177.

‡ *Proc. Phys. Soc.* **24** (1911) 141.

§ *Practical Measurements in Radioactivity*, p. 24 (1912).

Sources of Inaccuracy in Gold-Leaf Electrometry

In radioactive measurements with a gold-leaf electrometer, we may expect the greatest accuracy when two nearly equal sources are being compared. The precision of such experiments is limited mainly by the following considerations:

(1) The natural leak of the instrument may vary appreciably during the observations.

(2) The usual method of timing the rate of movement of the gold-leaf involves a number of possible errors, both instrumental and personal.

(3) Ionization by a radioactive substance is subject to fluctuations which limit the reliability of any finite number of observations.

(4) In addition to these fluctuations, the ionizing power of a source may be modified by incidents in its history other than its decay, such as alterations in the distribution of the material, or in the orientation of the source with respect to the electrometer.

(5) If the electrometer case is not air-tight, changes in density of the enclosed gas may alter the sensitivity of the instrument during the measurements.

(6) Exposure of the exterior to heat radiation, even if of only slight amount, may set up in the enclosed gas minute convection currents which considerably affect the movements of the delicate leaf.

Further reference will not be made to the last two possible defects, methods for remedying which are sufficiently obvious. It may however be mentioned that castings of either brass or aluminium are difficult to render air-tight, owing to the extensive occurrence of pores throughout the material. This may be overcome, however, by applying several coats of vacuum wax to the exterior, the instrument meanwhile being evacuated and heated. The efficiency of the seal may conveniently be kept under observation by permanently attaching a manometer to the instrument.

The other considerations above have all been studied in detail. And in order to determine the best methods of minimizing these difficulties, a large number of electrometers of different patterns have been constructed, and their characteristics investigated.

(1) *The Natural Leak*

(*a*) *General.* In precision electrometry, the magnitude of the natural leak is of considerable importance, since there occur from time to time fluctuations in this leak of from 5 to 10 per cent., and occasionally of even larger amounts. These random fluctuations obviously limit the reliability of the observations. Thus with a natural leak of 0·2 volt per minute, the fluctuations will be of the order of 0·02 volt per minute, and these may introduce errors greater than 1 in 1000 in all measurements in which the leaf is discharging at a rate less than 20 volts per minute. As this is a very convenient maximum rate to employ, with the usual magnification and eyepiece scale, it is desirable that the natural leak should be as low as 0·1 volt per minute, if possible.

The natural leak may be due to loss of charge either over the insulation or through the gas. Of these, the former can be practically eliminated by adopting Wilson's* device of permanently connecting the conductor above the insulation to the high-tension battery by which the leaf is charged. By completely evacuating the electrometer, and attaching it in this way to a 200 volt battery, it has been found possible to reduce the loss of potential of the leaf to less than one volt per day. Even this leak probably occurred through the residual gas.

* *Proc. Roy. Soc.* **68** (1901) 151.

The natural leak through the gas in the instrument may be due to some or all of the following causes:

(i) Emanation present in the gas, or active deposit on particles of dust suspended in it.

(ii) Contamination on the walls of the ionisation chamber.

(iii) Acquired or natural radioactivity of the materials of which the instrument is constructed.

(iv) Radioactive material in the neighbourhood of the electrometer.

(v) "Cosmic" radiation.

It is impossible to eliminate contamination of types (i) and (ii), if the electrometer is assembled in a radioactive laboratory in which contamination has ever occurred. Scouring the interior with hot nitric acid, then polishing with fine emery paper, and finally filling with dry, filtered air, are effective means of reducing the contamination. But such a process should be carried out in the open air, away from all possible contamination, and the instrument sealed up before being introduced into the laboratory.

An electrometer treated in this manner had a natural leak in a radioactive laboratory before treatment, of 0·6 volt per minute, and after treatment, 0·22 volt per minute; but on its removal to a laboratory where there had never been any radioactive material, this fell to 0·16—a decrease no doubt due to the elimination of cause (iv). A similar instrument made entirely in the latter laboratory had a leak of only 0·10; a value which corresponded to the formation of about 10 ions per c.c. per second.

Instances of natural leaks corresponding to values of q (number of ions per c.c. per second) less than 10 have been recorded in only exceptional cases. Thus Wright* found $q = 6$ in a zinc vessel over the surface of Lake Ontario; and Cooke† gives $q = 7{\cdot}5$ in a brass vessel.

It seems then that a natural leak of the order of 10 ions per c.c. per second is about the minimum to be expected under normal conditions. The portion of this now known to be due to the "cosmic" radiation of Hess, Kohlhorster and Millikan‡, and the portion due to the natural radioactivity of the air and the earth cannot be eliminated without such screening as would, for most purposes, make the instrument useless. Further improvement can be expected only through the selection of a suitable wall material having a natural radioactivity as small as possible. In general, this property is characteristic chiefly of elements of low atomic number. But if a high activity in the elements of high atomic number is due to the presence of radioactive material of relatively short life, the possibility arises of obtaining favourable results with ancient samples of these elements.

Thus a surprisingly low result was secured with an instrument constructed out of old lead, accredited to have been in use for at least 400 years. This electrometer had a natural leak of only 0·10 volt per minute, corresponding to $q = 9$.

(*b*) *Natural Leak in Relation to Sensitivity*. In many experiments in which the gold-leaf electrometer may be employed, the actual magnitude of the natural leak is not of as great importance as the value of the ratio

$$R = \frac{\text{natural leak}}{\text{specific sensitivity}},$$

where the quantity, specific sensitivity (S), may be defined, for convenience, as the rate of loss of charge, in volts per minute, for the electrometer when exposed to a standard γ-ray source, say, 10 mgm. of radium in equilibrium, placed at a standard distance, say, one metre, from the centre of the instrument; the leaf being charged to a standard average potential, say, 200 volts, and the electrometer being screened by a standard thickness

* *Phil. Mag.* **17** (1909) 295.

† *Phil. Mag.* **6** (1903) 403.

‡ *E.g.* Millikan, *Phys. Rev.* **27** (1926) 353 and 645.

(3 mm.) of lead. Thus, when the requirements demand an instrument of limited size, or when the actual or effective activity of the source is limited, accurate results will depend on the reduction of this ratio R to a minimum.

This specific sensitivity, for a γ-ray electrometer, depends on the following factors:

(i) Nature of the material lining the interior.
(ii) Nature of the enclosed gas.
(iii) Thickness and material of the walls of the instrument.
(iv) Volume of the interior.

With a view to employing the electrometer successfully in experiments on γ-ray absorption, already published*, in which sources of very limited effective activity were employed, special attention has been devoted to all these points.

(i) *Nature of the Lining.* A considerable amount of data has been published on comparative values of the quantity S for various metals; and in most cases it has been apparent that S increases with the atomic number of the material; so that, among the metals commonly available, lead is the most suitable in this respect. Few data have however been published on which one might base estimates of the value of R for various substances. In order to investigate this ratio, a series of instruments were constructed of various materials, and with various internal linings. Thus metallic linings were deposited on glass by silvering and subsequent electrolytic deposition, and by cathodic sputtering; or on other metals by mixing the metal with a little tin and soldering. The information gained in these experiments is summarized in Table I.

Table I

Lining material	S	q	$R = q/S$	Remarks
Aluminium	11·4	10	·88	
Glass	13·2	41	3·1	A bad sample
Iron	14·1	13	·92	
Copper	15·9	15	·94	
Brass	15·1	13	·86	
Zinc	14·3	9	·63	
Silver	15·2	14	·92	Impure
Tin	18·4	12	·65	
Old lead	26·5	9	·34	With a little tin

From this standpoint, aluminium is thus not a suitable material; zinc and tin are considerably better; but again the old lead has proved to be by far the best lining for the interior.

(ii) *Nature of the Enclosed Gas.* The values of both S and q vary for different gases used in the electrometer. In the early days of radioactivity, much attention was paid to both magnitudes for many gases; but the published data are in general inadequate to allow comparative values of R to be deduced. Measurements were therefore made of both quantities for several gases, by introducing them in turn, after adequate drying and filtering, into an aluminium electrometer. Table II summarizes the results obtained.

Table II

Gas	S	q	$R = q/S$
Air	11·4	10	·88
Nitrogen	10·7	10	·93
Carbon dioxide	17·3	10	·58
Sulphur dioxide	24·0	8	·33
Hydrogen	1·93	13	1·55
Oxygen	13·6	11	·81
Argon	16·4	13	·79

* *Phil. Mag.* in the press.

It is of interest to note that the superiority of sulphur dioxide in this respect depends on both its larger ionization current and its smaller natural leak current.

Increase of pressure in the gas contained in an electrometer constitutes a further method of decreasing the ratio R. Both factors are involved in this.

Since γ-rays are not wholly absorbed in vessels of the size of the present instruments, even when the gas is enclosed under very great pressure, increase of pressure produces a rise in the specific sensitivity approximately proportional to the increase in density. The natural leak, on the other hand, is largely due to α particles, which are generally completely absorbed in the enclosed gas when at atmospheric pressure. Hence an increase of pressure does not result in any great rise in natural leak. Thus, by using sulphur dioxide in one of the electrometers at two atmospheres pressure, the values of the constants obtained were, $S = 111{\cdot}0$, $q = 10$, $R = 0{\cdot}090$.

In consequence of these innovations, the value of R has thus been reduced from 0·88, for an electrometer of aluminium, filled with air at atmospheric pressure, to 0·090 for one lined with old lead, and filled with sulphur dioxide at two atmospheres. Such a tenfold decrease in R means a very considerable increase in the accuracy attainable in experiments with an electrometer of limited dimensions, and a source of limited activity.

(iii) *Thickness and Material of the Walls of the Instrument.* If a metallic lining of low radioactivity be thick enough to stop all α particles, the α-ray activity of the walls of the instrument is not of importance; but the nature and thickness of this material will affect the amount of γ-rays which penetrate from the exterior. It is advisable to provide some adequate screening material, in order to stop the softer scattered radiation which is always incidental to γ-ray work. For this purpose it has become customary to envelope standard instruments with from 2 to 6 mm. of lead.

If the vessel itself is composed of material of high absorption coefficient, account must also be taken of its thickness in deciding the amount of material suitable for the envelope. With instruments of the earlier cubical shape no difficulty occurs. But with those having a spherical interior, the thickness of the walls is in places considerable, and it is desirable therefore to select for the wall material a substance of low absorption. For this reason, a distinction has to be drawn between the material of the walls and that of the internal lining.

In all the later instruments here evolved, the vessel has been made of aluminium or brass, the lining, where present, being of old lead; while the whole instrument has been enveloped in a lead case 3 mm. in thickness. In this way, full advantage has been taken of the low value of R recorded above.

(iv) *Volume of the Interior.* The value of the ratio R has been found experimentally to be approximately inversely proportional to the volume of the electrometer. Thus, when the experimental conditions do not limit the size of the vessel, the simplest method of increasing the sensitivity of the instrument is by increasing its volume.

(2) *Measurements of the Rate of Movement of the Gold-Leaf*

While the accuracy of measurements made with a slowly moving leaf is limited by fluctuations in the natural leak, with faster movements the limitation is imposed by the accuracy of the timing methods employed. This in general is not dependent so much on the delicacy of the timing mechanism as on the length of time during which the point of the gold-leaf under observation appears to coincide with the division marks of the eyepiece scale.

Even with a good scale, this interval was found to be of the order of a half-second when the leaf was moving at the rate of about 20 divisions per minute. Now, for accuracy of

1 in 1000 in the timing of a leaf moving at this rate for two minutes, that is, over 40 divisions —which is about the maximum length of scale over which the leaf can be kept in focus, with the type of microscope usually employed—the timing error at each end must not *exceed about 1/10 second.* Apparent coincidence must thus occur over a scale distance of not more than 1/30 of a scale division.

In order to reduce this time to a minimum, several innovations have been introduced.

(*a*) *The Pointer.* A piece of the finest Wollaston wire is attached to the end of the leaf by a little thin shellac varnish, and thus a sharply focussed line is obtained in the eyepiece, of about the same width as a line of the scale, viz. 1/100th of a scale division.

Quartz fibres serve almost as well, and are easier to prepare and attach.

(*b*) *The Automatic Record.* Perhaps the most formidable source of inaccuracy in electrometry arises from the personal and instrumental errors involved in starting and stopping a watch while observing the coincidences in the microscope. Some automatic method of

Fig. 1

recording the leaf movement would obviously be more satisfactory, especially with rapid movements. After experimenting with a number of possibilities, the following scheme was adopted.

A magnified shadow of the pointer was projected upon a moving-film camera, fitted with a cylindrical lens. Adequate illumination was provided by concentrating on the pointer the rays from a pointolite lamp, by means of an achromatic condenser. The beam passed to the electrometer through a heat filter, and left the electrometer by a window of optically plane glass. The film was driven by a motor, with speed-reducing gears, and a fly-wheel. On the inner surface of the camera lens was etched a millimetre scale; and both this and the pointer threw upon the film shadows which produced fine lines on the moving film. A time scale was provided by rotating in front of the camera a toothed wheel, driven by a tuning fork, and providing 1/10th second or 1/40th second intervals, as required.

Fig. 1 is a portion of a typical record produced by this apparatus, and represents a leaf movement of about 73·2 divisions per minute. The scale lines are here horizontal, the time scale vertical, and the shadow of the pointer runs diagonally across the exposure.

From measurements made on the film after development, it is possible with practice to estimate the time of a coincidence to within 3 or 4 hundredths of a second. A single estimate of the time interval for 25 divisions may thus be made to about 1 in 500, and the average of a number taken from the same film should thus be in error by not more

than 1 in 1000. The data in detail for five consecutive films, including the one of Fig. 1, are reproduced in Table III.

Table III

Times in seconds for 25 divisions

Film no. / Scale interval	48	49	50	51	52
0–25	20·44	20·48	20·47	20·44	20·45
5–30	·49	·50	·49	·46	·50
10–35	·53	·54	·57	·54	·55
15–40	·57	·55	·59	·63	·57
20–45	·59	·56	·61	·64	·63
25–50	·64	·66	·64	·68	·68
Means	20·54	20·55	20·56	20·57	20·56

Since the time-base shows that the film is moving at a sufficiently uniform rate, Table III indicates that the leaf has a slight acceleration (as might be expected from the manner in which the field obviously varies over the path of the leaf); but the results prove that this does not appreciably affect the accuracy of the deductions. In Table IV, a summary is given of the rate deduced from 20 consecutive films.

Table IV

Times in seconds for 25 divisions

Films 40–49	Films 50–59
20·53	20·56
6	7
4	6
6	4
4	5
6	4
6	5
7	6
4	5
5	6
$20{\cdot}55_1$	$20{\cdot}55_4$

These typical results are sufficient to substantiate the claim that the method is capable of an accuracy of at least 1 part in 1000. It seems hardly necessary therefore to analyse possible sources of error in this method. But attention has been given to the reliability of the time intervals, and to the possibility of film shrinkage, with quite satisfactory results.

When this camera method is employed, it is a convenience to be able to observe the movement of the pointer directly. By allowing a portion of the beam between the instrument and the camera to fall on a 45° mirror, the shadow of the pointer may be thrown on a galvanometer scale, and its progress followed by eye. For slow movements of the leaf, this shadow may be timed with a stop-watch with much greater accuracy, and with much less eye-strain, than is attendant on the usual method of observation.

Fast movements of the leaf create no difficulties for the camera, until the speed of the film becomes too great for the photographic sensitivity. Satisfactory records have been obtained with the pointer moving at a rate of as much as 292 divisions (about 36·5 volts) per minute, the film speed being about 4 metres per minute, and the time-base providing fortieths of seconds.

The instrument is capable of adaptation to lecture-table purposes, since with adequate illumination, the pointer may be magnified several hundred times, and projected on a screen.

(3) *Radioactive Fluctuations*

Fluctuations occur in the number of γ-rays emitted by a source, and in the number of ions produced by each γ-ray in the electrometer. In regard to such fluctuations, Campbell* has shown that, in an estimate of the average number (N) of events occurring in a given time, and conforming to the probability law, the relative error is equal to $1/\sqrt{N}$. Now the number of ions required to reduce the potential of an electrometer by a given amount is independent of the rate at which this occurs. Consequently the error due to fluctuations should be a constant of the instrument. With an electrometer of capacity 1·4 cm., for a potential change of 4 volts, the value of N is about 25×10^6; so that the error due to fluctuations in this instrument should be of the order of 1 in 5000.

This theory has not been borne out by experience; for it has been found that the consistency of sets of measurements varies with different instruments in such a way as to suggest that it is dependent in part on the shape of the interior. Thus an electrometer with a spherical interior has been found to give appreciably more consistent results than a cubical one; and when the shape of the interior was modified to give a more symmetrical field, by making it cylindrical with hemispherical ends, the consistency was found to have increased still further. No adequate explanation has been found for this peculiar result.

(4) *Characteristics of the Source*

A discussion of the accuracy of an electrometer used for comparing γ-ray sources can hardly be complete without some reference to the idiosyncrasies of the sources to be compared. These usually consist of sealed glass or metal tubes or capsules containing emanation or a radioactive salt (either pure, or admixed with inactive material). In the case of emanation, the active deposit will be distributed on the walls of the tube. With a solid, the distribution of active material will largely depend on whether the tube is full or not. The observed activity is thus liable to alter if the material is displaced in the tube, if the tube is measured first on its side and afterwards erect, or even if a change is made in its orientation with respect to the electrometer. This latter alteration has been found to change the effective value by as much as 1/5 per cent.; while the other alterations may cause much larger variations.

In view of these facts, it seems advisable, in designing and handling a standard for accurate radioactive measurements, that the standard should be of pure and concentrated material, occupying as nearly as possible the whole of the tube, should at all times be kept in an erect position, and should be employed with the same side always presented to the electrometer.

It is not necessary for accurate comparisons that two sources should have approximately equal activities. In fact, reliable results have been obtained with sources differing in value as widely as 36 to 1.

Further, it is not necessary that the two sources should be placed at the same distance from the centre of the electrometer. If this distance is not less than about 40 cm., and if due allowance is made for the absorption of the air, in accordance with the data of Chadwick†, it has been found that the inverse square relationship may be applied with considerable accuracy. Thus sources of widely different values may be compared under the most favourable conditions by exposing them in turn at different distances from the instrument. In this way, the range has been extended to sources in the ratio of 14 to 1 with an accuracy of about 1 in 500. Taken in conjunction with the results mentioned above, the range is thus extended to sources differing in ratio as widely as 500 to 1.

* Campbell, *Proc. Camb. Phil. Soc.* **15** (1909) 117.
† Chadwick, *Proc. Phys. Soc.* **24** (1912) 152.

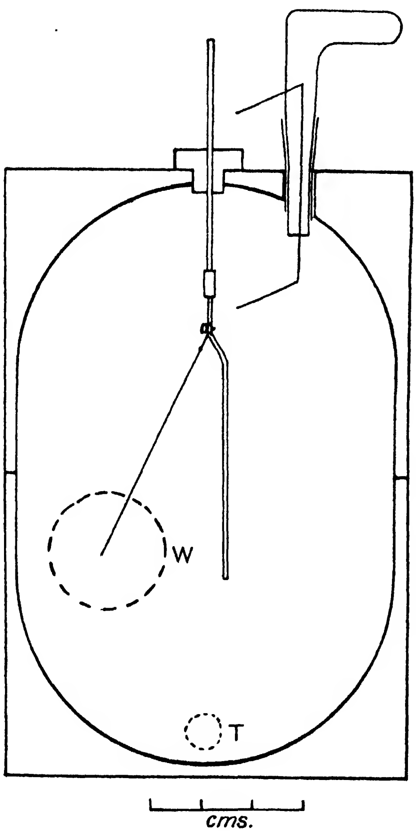
Fundamental Assumption

All comparative radioactive measurements are based on the fundamental assumption that the rate of movement of the electrometer system under observation is strictly proportional to the amount of ionization, and this in turn to the activity of the source.

This assumption was here verified by measuring the separate and combined effects of two γ-ray sources at a large variety of distances, when it was found that the effects were accurately additive, within the experimental limits of about 1 in 1000, for leaf movements ranging from 10 to 300 divisions per minute.

General Conclusions

It now remains to summarize the information gained in regard to the construction of a delicate γ-ray electrometer, and to refer to some further details which experience has shown to be of importance.



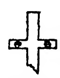


Fig.2a.

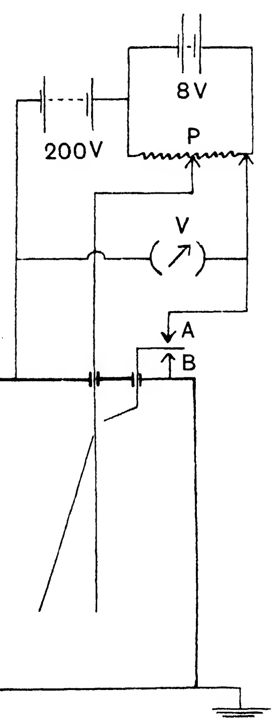


Fig. 2

Fig. 3

The instrument is of brass, cast in two portions, which are fastened together by bolts passing through the four corners; its internal shape is that of a cylinder, capped by hemispheres (Fig. 2). The interior is coated with a thin layer of old lead mixed with a little tin. The exterior is completely covered with sheet lead, 3 mm. in thickness. Plate glass windows, *W*, attached by wax, cover two apertures in the lower half of the case, about 2 cm. in diameter, and these are protected from scattered γ radiation by tubular screens of lead. The instrument is further enclosed in an asbestos case, to screen it from heat radiation.

A wire projects through an ebonite stopper in the top of the case, and carries a bead of sulphur to insulate from it the electrode and gold-leaf suspended below. The top of this electrode is provided with a tiny cross-bar (Fig. 2 *a*), and the leaf is clamped between this and another tiny strip of metal screwed to it; thus a definite hinge-line is provided for the leaf. Below this point the electrode is bent slightly, to prevent the leaf from adhering to it when uncharged. The leaf, about 2 mm. in width, and 4 cm. in length, has attached to its extremity a light pointer of quartz or Wollaston wire.

The pointer is strongly illuminated, and projected by a suitable optical system, giving a magnification of some 40 diameters at a distance of about 40 cm. The rate of movement of the image may be measured either by a moving-film camera, timed by a phonic wheel with sectors, or by visual observations with a scale and stop-watch. It is convenient to be able to use either method at will, as the former is more accurate for rapid movements of the leaf, and the latter for slow ones.

Charging is effected by a high-tension battery, one terminal of which is connected to the case and to earth, the other to a potentiometer having a potential difference between its ends equal to the voltage change experienced by the leaf during a measurement (Fig. 3). The centre of this potentiometer is permanently connected to the wire supporting the leaf system; while the high-potential end is brought into contact with the charging lever at A, when this is rotated so as to touch the internal electrode. In the off position B, this charging wire is connected externally to the case. The voltage of the battery is kept under observation by the aid of an electrostatic voltmeter, V. Thus the electrode is maintained at the average potential of the leaf during operations, and the division-per-volt sensitivity can be kept constant during an experiment.

The electrometer may be filled with dry, dust-free air, and sealed. Or if only feeble sources are available, sulphur dioxide may be introduced under two or three atmospheres pressure through two tubes (T) in the bottom of the case. The constancy of the pressure may be checked by a manometer, permanently attached.

In a great variety of experiments with this instrument, typical examples of which have been quoted here, an accuracy of at least 1 part in 1000 has consistently been maintained. Such an electrometer may thus with confidence be included among the precision instruments of a physics laboratory.

I have much pleasure in acknowledging my indebtedness to the Government Grants Committee of the Royal Society for providing means for the purchase of the camera and other accessories; and to Messrs Watson and Sons (Electro-medical), Ltd., for the loan of a 10 mgm. source of radium.

AN INSTRUMENT TO RECORD THE CARBON DIOXIDE CONTENT OF A GASEOUS MIXTURE. By K. GORDON AND J. F. LEHMANN

[*MS. received, January 9th*, 1928.]

ABSTRACT. The carbon dioxide recorder here described is based on the variation in concentration of the bicarbonate salt in equilibrium with a saturated solution of the carbonate of an alkaline earth, preferably barium. The bicarbonate concentration is dependent upon the carbon dioxide partial pressure in the gas passed through the solution, and is measured by determining the electrolytic conductance of the solution. By using a recording A.C. milliammeter to measure this conductance a continuous record is obtained of the carbon dioxide in the gas.

The readings of the instrument are independent of the gaseous constituents other than carbon dioxide. It can therefore be used when other recorders are inapplicable owing to the simultaneous variation of several constituents of the gas to be analysed.

MANY carbon dioxide recorders have been based on the fluctuations in a physical property of a gaseous mixture, produced by changes in carbon dioxide content, *e.g.* the katharometer. Should the constituents other than carbon dioxide also vary, the observed fluctuation will be due to the combined variation of many constituents, and cannot be expressed in terms of carbon dioxide concentration. The instrument described below was designed to record the carbon dioxide concentration in gaseous mixtures, all the constituents of which were subject to simultaneous fluctuation.

The instrument is based on the variation in the equilibrium concentration of the carbonate and the bicarbonate salts of the alkaline earths, produced by an alteration in the partial pressure of carbon dioxide in contact with the solution. The solubility of the carbonate is very much less than that of the bicarbonate, so that the conductivity of the solution is determined by the bicarbonate concentration, which in turn is dependent upon the carbon dioxide concentration of the gas in contact with the solution. Thus the gaseous carbon dioxide concentration may be determined by measuring the electrolytic conductance of the solution. Of the various alkaline earths barium has proved the most sensitive to small fluctuations in carbon dioxide concentration. The sensitivity increases with increasing atomic weight, magnesium being very insensitive.

The relationship between the electrolytic conductance and the carbon dioxide concentration may be deduced from a simple application of the law of mass action.

Referring to the reaction

$$BaCO_3 + H_2CO_3 \rightleftharpoons Ba(HCO_3)_2,$$

it is evident that, given an excess of solid barium carbonate, the concentration of dissolved barium carbonate will be constant at its saturated value, and the concentration of barium bicarbonate will be proportional to the concentration of carbonic acid, and hence to the carbon dioxide partial pressure in the gas in contact with the solution.

Applying the law of mass action to the reaction

$$Ba(HCO_3)_2 \rightleftharpoons Ba^{++} + 2HCO_3^-,$$

we have

$$\frac{C_1}{C_2 C_3^2} = K,$$

where C_1, C_2 and C_3 are the concentrations of undissociated barium bicarbonate, barium ion, and bicarbonate ion, respectively; and K is a constant. The conductivity of the solution is proportional to C_2 and obviously $C_3 = 2C_2$. Therefore

$$C_1 = K'C_2^3, \text{ where } K' = 4K,$$

and the bicarbonate concentration is proportional to the cube of the conductivity of the solution. Since the bicarbonate concentration is directly proportional to the CO_2 concentration in the gas in contact with the solution, it follows that

$$P = AI^3 \qquad \text{......(1)},$$

where P is the percentage of carbon dioxide in the gas,

I is the current through the electrolytic cell,

A is a calibration constant depending on the chemical equilibrium coefficients, on the geometrical arrangement of the electrodes, and on the potential difference applied to the electrodes.

The apparatus used is indicated in Fig. 1. It was filled to a level FF with 40 cubic centimetres of a saturated solution of barium carbonate, having a considerable excess of solid barium carbonate present. The gas entered A, and was thoroughly scrubbed with the liquor in the spiral lift BC; a satisfactory gas flow was about 10 litres per hour. The conductance of the cell was measured either by a Kohlrausch bridge, or by measuring the current through the cell when a constant alternating electromotive force was applied to the electrodes. The latter method was used to obtain a continuous record of the carbon dioxide content of the analysed gas, the current being measured by a recording alternating current milliammeter.

Several calibration tests have been made. In these the carbon dioxide content was determined by an Orsatt and the conductance by a Kohlrausch bridge. The logarithm of the carbon dioxide content was plotted against the logarithm of the conductance and in each case a straight line was obtained with a slope of $3{\cdot}0 \pm 0{\cdot}2$; the mean slope being $3{\cdot}05$. Thus within the limits of experimental error equation (1) is applicable. The calibration constant A varies appreciably with temperature, and the instrument should be operated in a thermostat. A convenient temperature at which to maintain the thermostat is 50° C. At this temperature the time lag of the instrument is small (of the order of 1 minute).

The instrument has been in continuous operation for some months and its readings have checked well with routine Orsatt analyses of the plant gases.

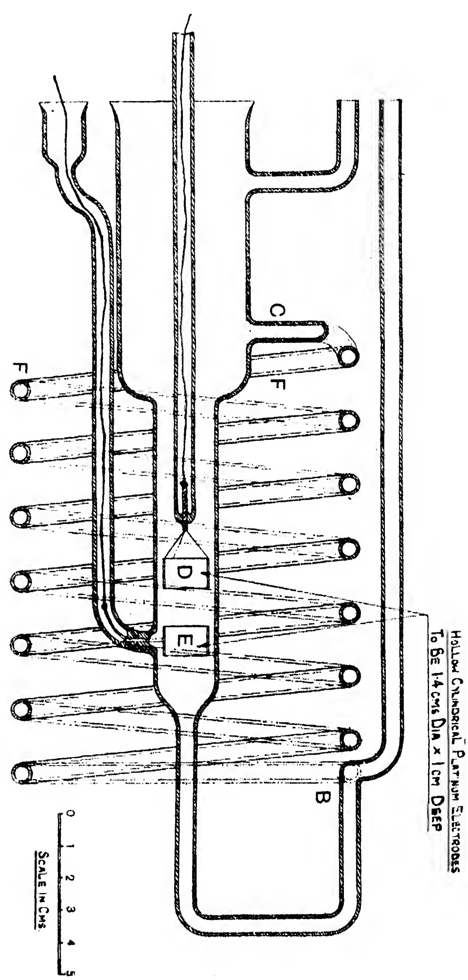


Fig. 1

Fig. 2 gives the calibration curve of the instrument when the conductance of the electrolytic cell was recorded by an alternating current milliammeter. The milliammeter used had a square root scale, and therefore the curves of Fig. 2 follow a 3/2 power law instead of the cubic law of equation (1).

The instrument may be operated over any desired range of carbon dioxide content, by altering either the potential difference applied to the cell or the distance between the

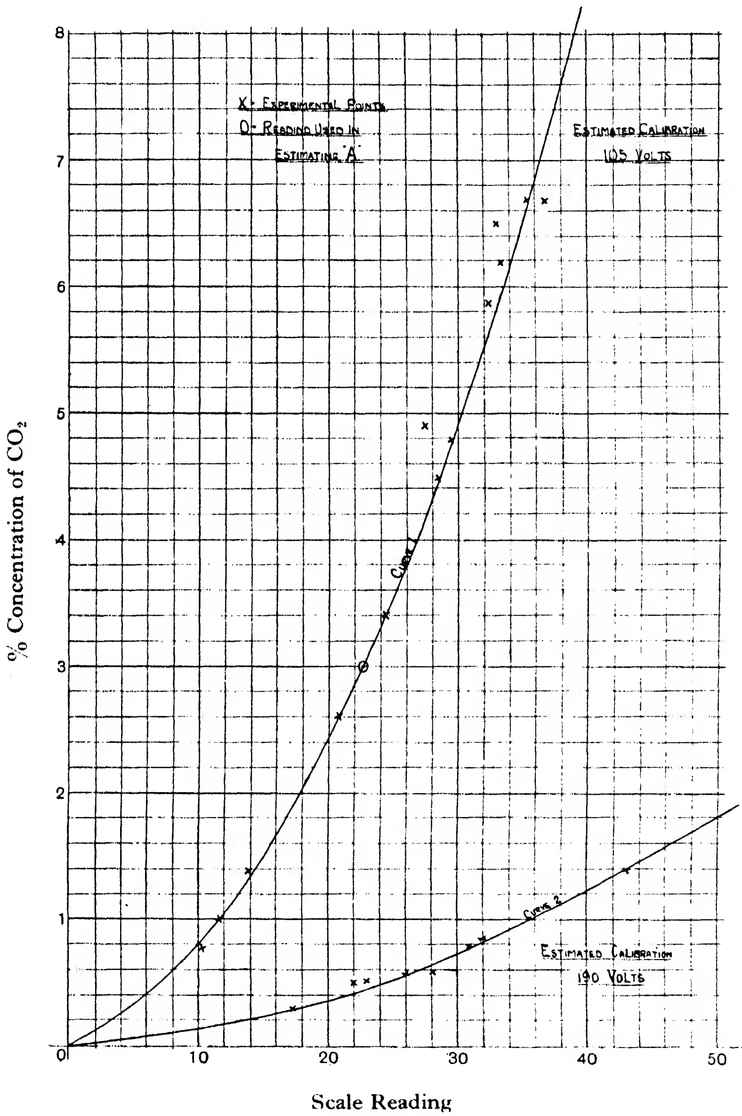

X - Experimental Points
O - Reading Used in Estimating "A"
Estimated Calibration 105 Volts
Estimated Calibration 190 Volts
Curve 1
Curve 2
% Concentration of CO_2
Scale Reading

Fig. 2

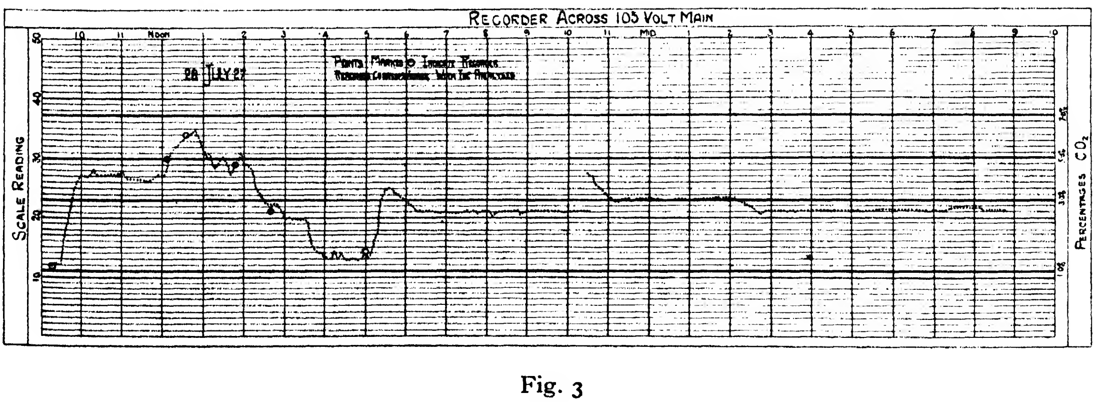

Recorder Across 105 Volt Main
Noon
Mid
Scale Reading
Percentages CO_2

Fig. 3

electrodes. In Curve 1 of Fig. 2, the applied potential difference was 105 volts and the range of the instrument was from 0 to 10 per cent. of carbon dioxide. In Curve 2 the applied potential difference was 190 volts and the range was from 0 to 2 per cent. of carbon dioxide. The full line curves of the figure were calculated using the reading marked ○ to determine the calibration constant A of equation (1). The points marked × were the Orsatt analyses of the gas passing through the instrument. In Fig. 3 a typical 24-hour record is reproduced. During the run shown in this chart the readings of the recorder were checked by an Orsatt analysis of the gas. The chart readings corresponding to the Orsatt analyses are indicated by the points ○.

The recorder here described was developed in the research laboratories of the Imperial Chemical Industries, Ltd., and the authors gratefully acknowledge their indebtedness to the directors of Imperial Chemical Industries, Ltd., for permission to publish their results.

A METHOD OF CALIBRATION OF A McLEOD GAUGE.

BY R. J. CLARK. Lecturer in Physics in the University of Edinburgh.

[*MS. received, 10th August, 1927.*]

ABSTRACT. A method of construction of a gauge of long range is described, and also a method of correcting for the error due to the meniscus in the capillary tube by shifting the whole scale of the instrument.

THE methods of calibration to be described lend themselves to making gauges of long range and great accuracy. The usual way of calibrating a gauge has been described at length in various books and papers, for example by Dunoyer, *La technique du Vide*, pp. 60 *et seq.* It is shown there that it is necessary to take account of the volume occupied by the meniscus in the capillary if great precision is required. A simple way of doing this calibration will be described, and also a method of construction which is quite easy.

Several gauges have been made at various times, and two, slightly different, are shown diagrammatically in Figs. 1 and 2. It will be seen that they are of ordinary pattern. The one shown in Fig. 1 can be baked out much more easily than the one shown in Fig. 2; the latter, however, is more compact.

To make a gauge, a piece of capillary of uniform bore and about 30 cm. long is required. To obtain this, a number of lengths of tube are cleaned by blowing steam through them, and dried. With ink, marks are made 10 cm. apart on each length, a column of mercury 30 mm. long is put in and the length of this is measured when one end of the column is at each mark successively. When a good enough piece is found, it is to be measured again more carefully at intervals of 5 cm. As an example of what is required we can take the measurements of the piece of tubing used in the gauge No. 2 (see Table I). The measurements were:

Position	15	20	25	30	35	40	45	50	55	60	65
Length	37·2	36·9	36·9	36·9	36·9	36·9	36·8	36·7	36·8	36·8	36·9

The tube was cut at the point 42·5 cm. and this point came at the top of the closed capillary (Fig. 2). The tube was sealed to the bulb near the point 15 cm. The other portion was used for the comparison capillary, and the point 65 cm. came at the level of the top of the closed tube when the gauge was assembled. This avoids unequal depressions of the meniscus in the two tubes.

Figs. 1 and 2 give a sufficiently general idea of the construction of the gauge. It is only necessary to point out that when the capillary is sealed to the bulb as short a length as possible should be heated in the flame. Further, to ensure that the same volume is always

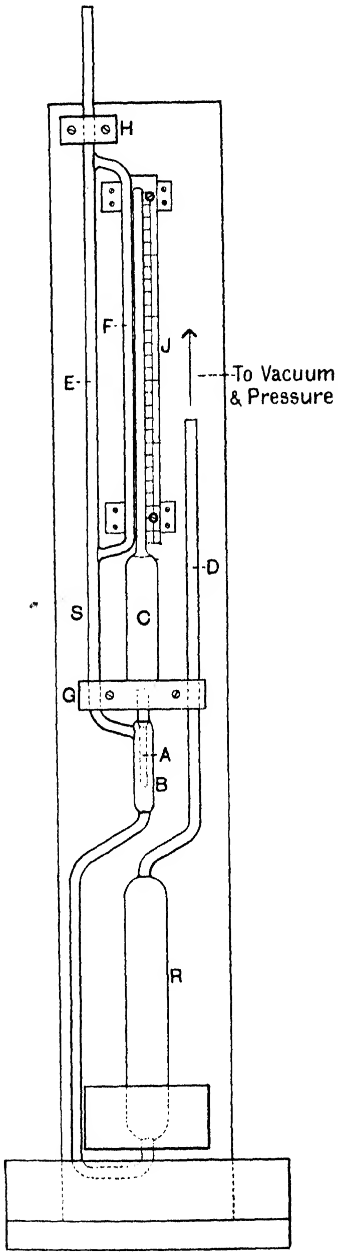


Fig. 1

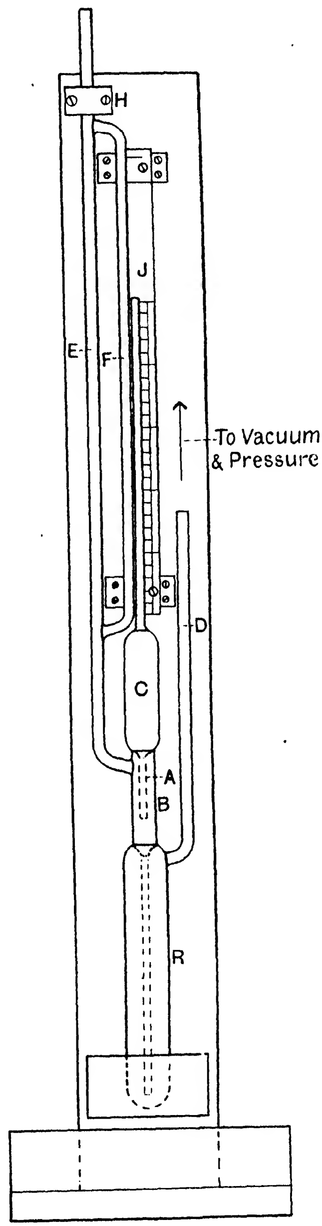


Fig. 2

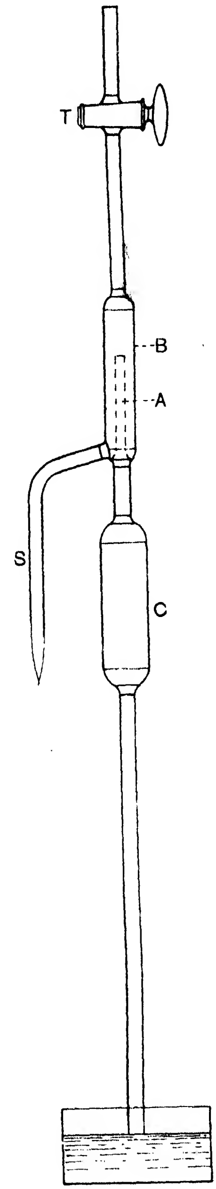


Fig. 3

cut off by the mercury, a re-entrant tube *A* projects into the tube *B* which goes to the reservoir *R* (see Fig. 1). This tube *A* should be of 3 or 4 mm. internal diameter, and this should be measured before the parts are sealed together. The tube *A* should be coaxal with the outer one, and its lower end should be cut quite square. The volume of the bulb

C may be from 25 to 50 cm.^{3}; a spherical bulb makes a shorter gauge than a cylindrical one and this is an advantage. In both patterns the mercury level is changed by changing the pressure in the reservoir. The tube D leads to a three-way tap. There is the usual wide bye-pass E to the comparison capillary F. Both gauges are shown mounted on boards, but if a gauge is to be baked out, it is best to mount it on a piece of $2{\cdot}5'' \times 2''$ T bar. The wooden supports G and H must then be replaced by metal ones, and the glass parts can be set in asbestos cement, for this will not harden too much when it is baked.

To calibrate the bulb and capillary, it is convenient to seal on a tap at T (Fig. 3). The side tube S is closed with the blow pipe, and the thoroughly clean and dry bulb is supported vertically in a stand, with the open end of the capillary dipping into a dish of mercury. By judicious exhaustion the mercury can be drawn up until a little of it runs over the top of the tube A. The tap T is closed, and by raising the bulb carefully, the top of the meniscus can be brought level with the top of the inner tube. After noting the height of this meniscus the end of the capillary is closed with the finger, the bulb lifted out of the dish, and the mercury run out through the capillary and weighed. This will give V_1, the total volume of the bulb and the capillary, after a correction has been applied for that portion of the inner tube A not filled by the mercury. This correction can be found from the tables of the volume of a mercury meniscus, for it is small and need not be known very accurately.

To determine the cross-section, a, of the capillary a long thread of mercury extending from the open end to not less than 15 mm. from the bulb is now put into the tube, its length is measured, it is run out and weighed, and the area is found from the mean of two or three determinations. If great accuracy is wanted it may be necessary to calibrate the tube by means of a very short thread of mercury. Directions for doing this will be found in works on precision thermometry, and the results can be expressed by a curve giving the deviation from the volume of the cylinder included between one end of the tube and a section l cm. distant; that is, we can write for this volume $v = al - \delta v$ and δv can be read off from the curve.

The top of the capillary must now be sealed. To do this, the open end is heated for a few mm. only and a small bead of hot glass is placed on the open end and melted down. This makes an abrupt end to the bore. To find the small decrease in the volume due to this sealing, a piece of gummed paper is first stuck on the capillary, and the length is measured from a mark on it to the end about to be sealed. After sealing, this length will be less by δx and the volume $a\delta x$ may be subtracted from the total volume and thus $V = V_1 - a\delta x$. These are all the measurements required before the gauge is assembled.

The gauge is next put together. The tap T is cut off, the different parts are washed if necessary, dried, mounted and sealed together. A drying tube should be used for blowing into the gauge during the sealings. A scale J, which should be movable vertically through a few mm., is fixed behind the capillary. Enough mercury is now poured into the reservoir R, or better, distilled into it in a good vacuum.

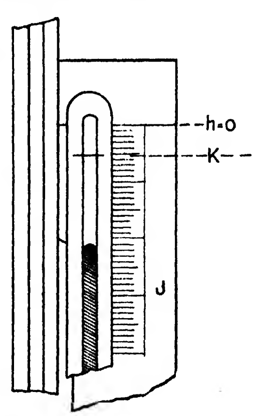


Fig. 4

The scale must now be set in its proper position. The bore of the capillary will be irregular at the top where it is sealed, and the volume of the upper x cm. of it will differ from the volume of a cylinder x cm. long, and a sq. cm. cross-section, by a small amount. As the capillary is rounded at the top end, it is not easy to say just where the bore ends. To avoid this difficulty we may make a mark K (Fig. 4) at a point on the outside of the tube just below the apparent position of the end of the

bore, and if we consider a length l of the tube measured downwards from this, then the volume of the tube will be greater than the volume of the cylinder l cm. long by a small amount v_1, so that the volume of the part is $v = la + v_1$. If we measure from the top of a meniscus to the mark K another small volume v_2 must be included because of the curvature of the meniscus, and so

$$v = la + v_1 + v_2 = la + \Delta.$$

It is clear that v_1 is a constant, and so for all practical purposes is v_2 as well, so that Δ is a constant. Now, if the mercury is raised to an arbitrary level in the open capillary, and the level in the closed capillary is then p cm. below this, and l cm. below K, then the equation for the gauge is

$$PV = (P + p)(la + \Delta).$$

Writing $la + \Delta = ha$, then

$$l - h = -\frac{\Delta}{a} = \text{a constant},$$

$$PV = (P + p)\, ha,$$

or

$$P = \frac{ph}{\frac{V}{a} - h}.$$

By changing the level at which $p = 0$ we may make $p = h$, and then

$$P = \frac{h^2}{\frac{V}{a} - h} \qquad \text{......(1)}.$$

Now h is measured from a point $\frac{\Delta}{a}$ cm. above the point K, and a scale arranged behind the capillary will read h directly if the mark K is $\frac{\Delta}{a}$ cm. below division 0 on the scale.

To find $\frac{\Delta}{a}$ the division 0 on the scale is set opposite K, the pressure in the gauge is reduced to about 0·01 mm., the mercury is raised to compress the gas into the capillary, and the gauge is pumped out as completely as possible. There is then a column of length l in the closed capillary, and if the meniscus in the open capillary is p cm. above that in the closed one, then $p(la + \Delta) = $ a constant. If p be changed to p_1, l will change to l_1 and $p_1(l_1 a + \Delta) = p(la + \Delta)$, and therefore

$$\frac{pl - p_1 l_1}{p_1 - p} = \frac{\Delta}{a} \qquad \text{......(2)}.$$

The zero of the scale is now set at a distance $\frac{\Delta}{a}$ above the mark K, and the gauge will read correctly at all points if the capillary is of uniform bore. It may be pointed out that the origin of h is not arbitrary, for wherever the origin of l be taken, that of h is always the same. If the mark K is less than a millimetre or so below the end of the bore $\frac{\Delta}{a}$ will be positive, so that the zero of the scale will be placed below the mark in this case. Since we have made $p = h$, the mercury in the open capillary is adjusted so that the top of the meniscus coincides with division 0 on the scale.

From equation (1) we can plot a curve for the gauge and read off the pressure corresponding to any scale reading. This method of calibration gives a gauge of long range with about the same expenditure of time and effort as is required to make one with several calibrated portions of the capillary. If moderate accuracy only is wanted, it is unnecessary

to calibrate the capillary tube for non-uniformity of bore. If the gauge is compactly constructed it will be possible, by using a longer comparison capillary, to have another mark for the adjustment of the mercury level some distance above the top of the closed capillary. This will give a gauge with two scales, one of which will be about twice the other. As an example we may give the data for two gauges. Neither of the capillaries was calibrated for uniformity of bore by a very short column of mercury.

Table I

Date	Gauge 1 May, 1924	Gauge 2 Nov. 1924
V	50·421 cm.³ at 16° C.	26·656 cm.³ at 16° C.
a	0·017647 cm.² 0·017649 cm.² 0·017645 cm.²	0·012413 cm.² 0·012410 cm.² 0·012415 cm.²
$\frac{V}{a}$	2857·2 cm.	2147·5 cm.
$\frac{\Delta}{a}$	0·0387 cm.	0·026 cm.
Length of capillary	25 cm.	26 cm.
Maximum P	2·207 mm.	3·188 mm. 1st scale 5·637 mm. 2nd scale
P for 1 cm. scale reading	0·00350 mm.	0·00466 mm.

The gauges were compared with one another, with the following results:

Table II

Gauge 1		Gauge 2		
Scale reading	P	Scale reading	P	Diff. per cent.
12·30	0·531	10·68	0·530	+ 0·19
13·23	0·614	11·46	0·612	+ 0·33
16·41	0·948	14·26	0·948	0·00
19·00	1·273	16·50	1·276	− 0·25
22·21	1·740	19·20	1·738	+ 0·15
	2·357	22·41	2·360	− 0·13

Apparently the accuracy is limited by the accuracy of reading on the scale, and if this were engraved on the capillary or were of metal it would be possible to do much better. The scales on both instruments were of boxwood, and were checked against a steel scale. They were placed just behind the capillaries, and the readings were taken with the naked eye. The gas was nitrogen at 17° C.

APPARATUS FOR THE DETERMINATION OF COEFFICIENT OF EXPANSION. By J. W. W. WILLSTROP, B.Sc., A.I.C.

[*MS. received*, 17*th December*, 1927.]

ABSTRACT. Apparatus for the determination of the coefficient of expansion of short lengths of metal is described and illustrated.

In any determination of the coefficient of linear expansion of a solid in which the expansion is measured by direct means, such as a micrometer, it is usually necessary to employ a bar of considerable length, say 3 to 5 ft., in order to obtain an increase in length sufficiently large to be measurable with accuracy. The apparatus described below was designed to enable

the expansion coefficient to be determined with precision of metals of which only short pieces of about one foot in length were available.

It consists essentially of two bars, both of the metal in question, or, preferably, one the metal and the other of another metal of known coefficient, suspended parallel to each other and in the same horizontal plane, as close together as circumstances will permit. Each bar is immersed in a separate bath, and while one end of each bar is fixed the other is pivoted on a stirrup carrying a vertical plane mirror and free to rotate about a vertical axis. An illuminated scale is viewed through the mirror by means of a telescope with cross wires, and from the shift observed when the temperature of the bath containing the bar of unknown coefficient is raised the actual expansion and hence the coefficient can be calculated. The influence on the final result of the expansion of parts of the recording apparatus has been reduced to a minimum.

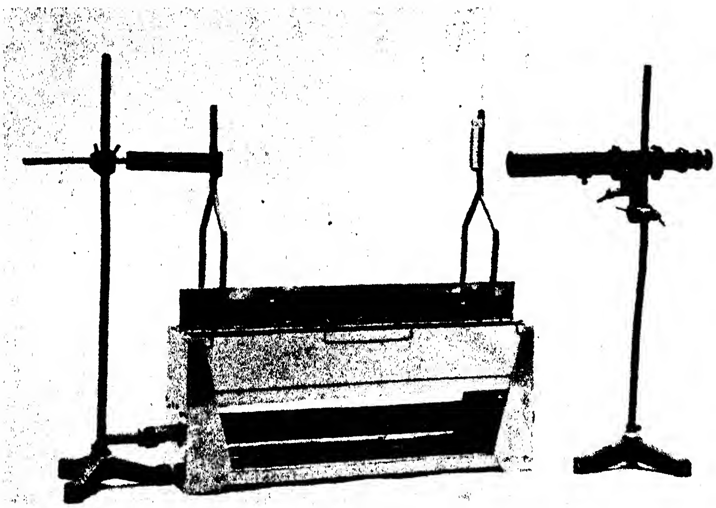


Fig. 1

The baths used were made of stout duralumin sheet and measured 16 in. long by 2 in. wide by 3 in. deep (see Figs. 1 and 2). They were mounted side by side in a stand with a space of $\frac{1}{4}$ in. between. Both baths were lagged on all sides with $\frac{1}{8}$ in. asbestos sheeting, and the one to contain the cold bar was also lagged on the bottom with the same material. Under the other bath, and extending the whole length, was mounted a gas burner.

A screen, extending from the base of the stand to two inches above the tops of the baths, was placed vertically between the baths to prevent radiation of heat to the cold bath. It consisted of an asbestos sheet covered on the hot bath side with polished sheet aluminium. A similar screen, not shown in Figs. 1 and 2, was placed horizontally across the top of the vertical screen in order to deflect the hot air rising from the hot bath, which otherwise caused irregular refraction effects and interfered with the viewing of the scale through the telescope. This horizontal screen was slotted to allow room for the legs of the stirrups carrying the bars.

The stirrups were made of well annealed $\frac{1}{4}$ in. square iron rod, and each carried two small agate cups mounted in brass housings which were screwed into the ends of the stirrups. Four hardened steel hooks resting in the agate cups served to support the bars. Holes to take the stems of the hooks were drilled near the ends of the bars and the hooks were firmly

attached by means of nuts. The movable stirrup was suspended from the top by means of a thin wire about four feet long.

The stirrups were fitted with plane mirrors, mounted to face each other; and an illuminated centimetre scale at a distance of about three metres from the movable mirror was viewed through both the mirrors by means of a telescope carrying cross wires.

The following measurements were made in order to calculate the expansion:

The distance between the hooks on each separate bar (l and l').
The distance between the hooks on the movable stirrup (s).
The distance of the scale from the movable mirror (r).

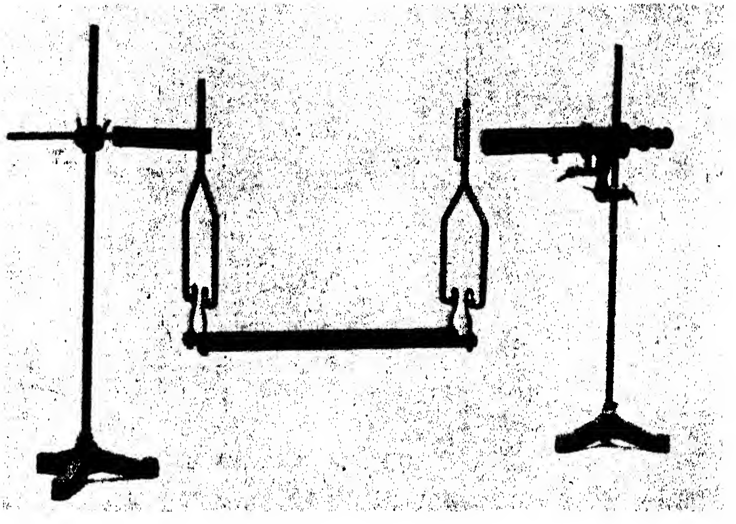


Fig. 2

The expansion of the hot bar with respect to the cold one is then equal to $as/2r$, where a is the movement on the scale and is small in comparison with r.

Any small expansion of the cold bar due to a slight rise in temperature is calculated and added to the observed expansion and from the initial and final temperatures of the hot bar the coefficient of expansion is calculated in the orthodox way.

The author wishes to acknowledge his indebtedness to the Director of Scientific Research of the Air Ministry for permission to publish the above description, and also to the Controller of H.M. Stationery Office for permission to reproduce the photographs from an official report.

Metallurgical Department,
Royal Aircraft Establishment.

A SIMPLE CONTROL UNIT FOR ELECTRICALLY HEATED MERCURY VAPOUR PUMPS.

By D. R. BARBER, B.Sc., Research Student, Dept. of Physics, University College of the South West of England, Exeter. (Communicated by Prof. F. H. Newman, D.Sc., F.Inst.P.)

[*MS. received, 7th December, 1927.*]

ABSTRACT. A simple type of heater control is described, designed for use with all types of mercury vapour pumps equipped with electric heaters.

If a mercury vapour pump is in operation over an extended period, it is advisable to have some means of regulating the heating supply, so that in the event of an interruption in the condenser water supply, the heater is automatically eliminated. Some form of automatic "cut-off" for the heater is required, and the author has found the simple design, described below, very effective. It has been expressly designed with the object of preventing serious contamination of the vacuum line with mercury vapour in such circumstances, and is based upon the principle of the U-tube manometer.

It consists of a glass tube A, 35 cm. long, and ·5 cm. bore, bent into the form of a U, its shorter limb terminating in a bifurcated portion B, 6 cm. long, and the longer limb joined to the condenser supply tube C. Mercury fills the U-tube to the level indicated by the dotted line in the diagram, and by its motion actuates the control. Two thick copper wires D, dipping into the short terminal tubes E, are connected in series with the heater H, and as long as the flow of water through the supply tube C is maintained, the elevated mercury column makes contact with the electrodes D, thus allowing a current to flow through the heating coils. When, however, the flow of water through the condenser ceases, the mercury in the tubes E falls, consequent upon a diminution of pressure over the mercury surface in the longer limb, and the heater circuit is thus automatically "broken." A layer of liquid paraffin F, over the mercury surfaces, serves to quench excessive sparking, when operating with high current densities.

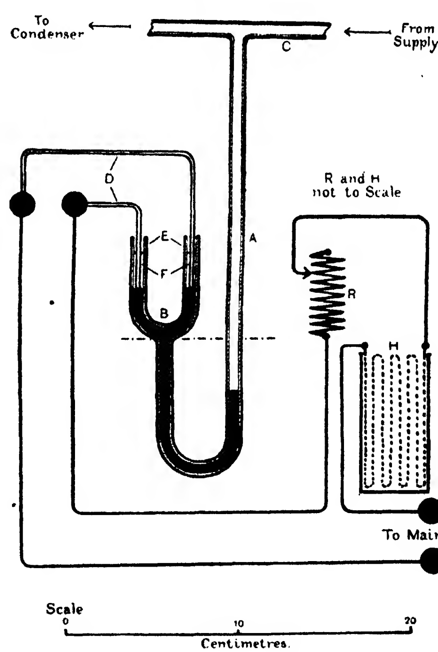


Diagram of the Control Unit, and its associated Electrical Circuit

Mercury vapour pumps, in general, are critical as regards the rate of evaporation, and thus for a particular heater unit, there will be an optimum value for the current passing through its coils. This may be found, and maintained constant, by the inclusion of a series rheostat R in the circuit. This control has been used by the author, in conjunction with a Volmer type of diffusion pump, fitted with a nichrome-wound heater, taking 128 watts, at 110 V. A.C.

When the unit is in operation, care should be taken that the electrodes are well below

the mercury surface, so as to prevent the possibility of intermittent contact at the electrodes, due to small fluctuations in water pressure. The mercury meniscus in the longer limb must also be well removed from the bent portion of the U-tube, as water may otherwise leak past the mercury seal into the electrode tubes.

The unit may be used with all types of condensation pumps, equipped with electric heaters.

NEW INSTRUMENTS

A NEW QUICK TUNING VIBRATION GALVANOMETER WITH CALIBRATED TUNING. By D. C. GALL.

In connection with the duplexing of submarine cables by the process described in Patent No. 262,991 it became desirable to have a vibration galvanometer which could be tuned to any frequency immediately, and which could be calibrated so that the tuning could be set

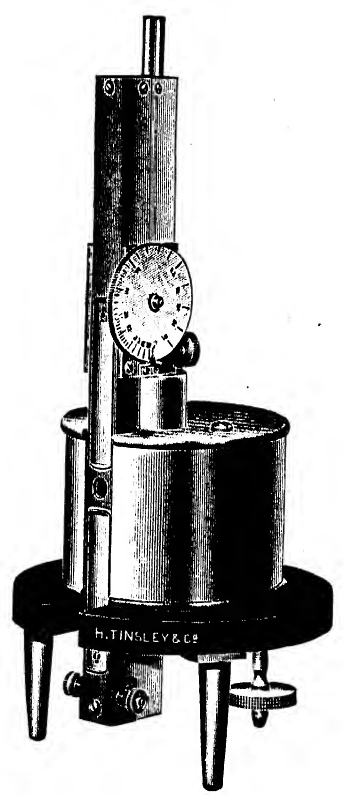


Fig. 1. New Quick Tuning Vibration Galvanometer

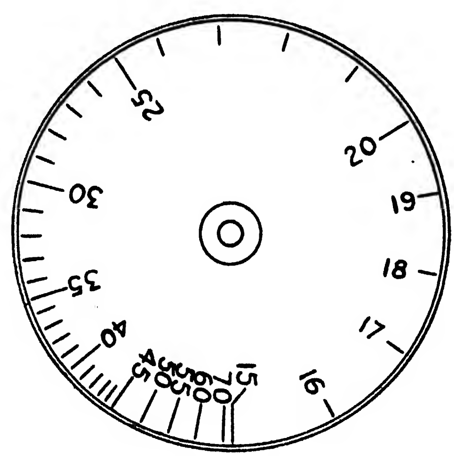


Fig. 2

and re-set as required without the usual process of tuning by trial. The range of frequency to be covered by the galvanometers is from 3 cycles per second to 300 cycles per second.

These requirements have been met in the instrument which is illustrated in Fig. 1 and made by Messrs H. Tinsley and Co. This is a modification of their standard pattern of Moving Coil Vibration Galvanometer. It is so arranged that the tuning is carried out by

the simultaneous adjustment of the position of the bridge pieces, between which the suspended coil vibrates, and the tension of the suspension strip itself. When the bridge pieces are at their greatest distance apart, the tension of the strip is least, giving the lowest frequency of vibration to the coil. As the bridge pieces are closed together, the tension is increased to a maximum, when they are closest, thus giving the maximum frequency of vibration to the coil. This process of tuning is carried out by turning the large milled disc at the side of the galvanometer until the desired frequency is opposite the index.

By making these adjustments simultaneously, a long range of adjustment is obtained, and Fig. 2 shows an actual scale of one of the galvanometers giving the calibration extending from 15 to 70 cycles. It will be seen that the scale is very much more open at the lower end. This gives about the same percentage accuracy of setting at all frequencies. Three suspension pieces cover the range from 3 to 300 cycles. The sensitivity of the galvanometer is of the same order as the old type.

The following are typical values:

D.C. Resistance of coil: 6 ohms.

Frequency	M/M's per Mc. volt	M/M's per Mc. amp.
50 cycles	2·3	41
60 ,,	2	37
125 ,,	1·88	12
200 ,,	0·13	0·75
250 ,,	0·17	0·65

THE RAMSDEN REFLEX MICROGRAPH

THE following description has been supplied by the designer of the instrument, Lieut.-Col. J. V. Ramsden, C.M.G., D.S.O., Whiston Priory, Ford, Shrewsbury:

This micrograph is essentially an inverted microscope system, comprising the usual objective and ocular, from which the rays pass to a mirror and are reflected forward and upwards on to a screen where they may be either visually examined, or a photographic plate may be substituted for the frosted screen and the image recorded by photography.

Closely adjacent to the main camera in the body casting is a secondary camera with separate lamp and lens, by which the image of a slip of paper, carried on a "label slide," may be projected on to the photographic plate. Such information as it is desired to record on the photograph is written on this slip of paper. A separate switch allows a low power lamp to illuminate the slip, and when the photograph is developed the information will be found on the negative. Those who have gone through the process of trying to write on an undeveloped plate in absolute darkness after taking it out of the slide, will appreciate this arrangement. Further, it is possible to place below the plane of the screen or photographic plate a transparency or ruled glass screen with appropriate scales, so that objects may be visually measured with the greatest ease, or their size recorded automatically on the photographs.

Particular pains have been taken in the mechanical design to make the instrument suitable for the hard work of industrial research or inspection. The instrument consists of an upper lamp house, so designed that Pointolite or projector lamps may be burnt with their caps downwards, as recommended by their makers. The light from this lamp house is thrown by a mirror down on to the condensers and stage. Both stage and substage are equipped with quick acting releases, so that one or both can be thrown out of the way when they are not required. This is a convenience which must be seen to be really appreciated. At the same

time these releases are so designed that the stages, when locked, must come back absolutely to their proper positions.

The stage and substage are carried on a very robust pillar, supported by a strong bronze bracket, which allows a great length between the bearings. The pillar is hollow, and contains a screwed rod, which acts as a coarse focussing adjustment. This rod bears on the short end of a 5 to 1 lever, of which the longer end abuts against a metal disc, which is pivoted with a very small eccentricity. This disc is very amply protected, and can be turned

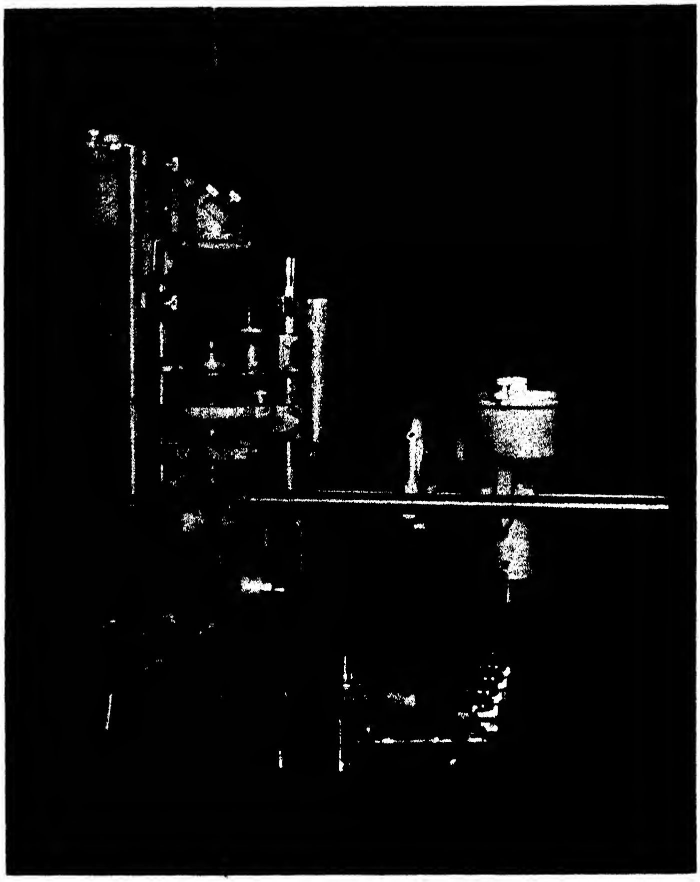


Fig. 1. Micrograph No. 5. Universal pattern for all work

by a large head of insulating material. The whole gives a remarkably smooth fine adjustment, with the minimum of bearing surfaces which can wear or be distorted. The bearings are easily adjustable, and after adjustment can be positively locked, without interfering with the adjustment.

For work on opaque objects a second lamp is provided with an optical illumination system and a special illuminator on the lines of that of Mr C. Beck, in which complete control of the reflector in all directions is given. This is particularly valuable in eliminating the "flare" from the back lens of the objective from photographs. Special models are available for biological work, and for petrology. In the latter the analysing prism and a lens for observing the interference figure can be brought in or out of action by interlocking heads.

Special attention has been devoted to the design of the stand, with a view to avoiding

vibration. The instrument having been primarily worked out by the designer for his own use, every part of the mechanism has been planned to allow of very rapid work, while still conserving the highest accuracy.

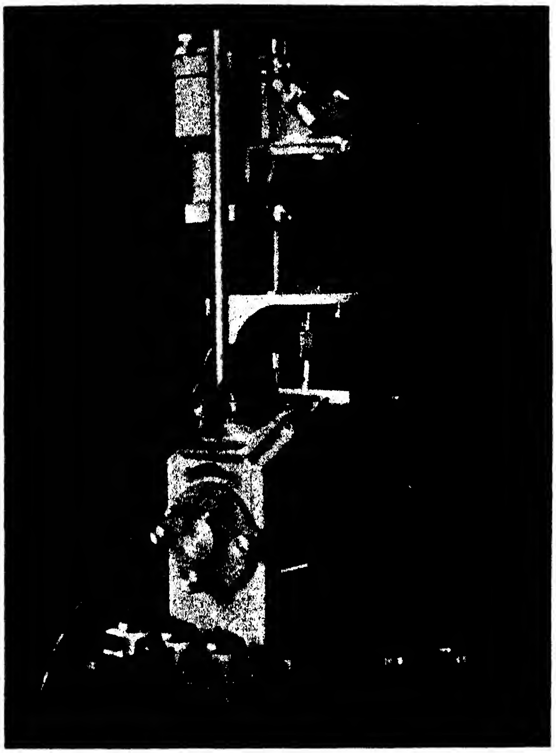


Fig. 2. Micrograph No. 7. For routine work on transparent objects

LABORATORY AND WORKSHOP NOTES

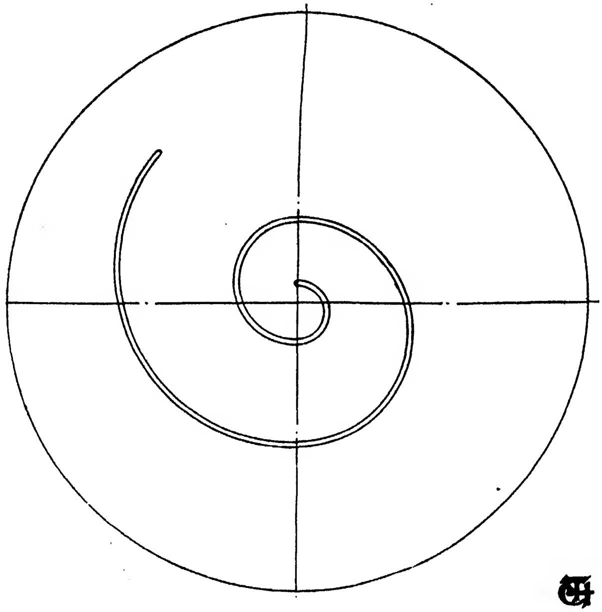
FLAT SPIRAL SPRINGS

A FLAT SPIRAL SPRING forms a very convenient means of guiding and effecting small displacements. Its ends can very readily be secured to the two elements whose relative movement is to be constrained, when it acts as a key against rotation, and permits only motion perpendicular to its plane, acting equally well both in compression and in tension. It is more compact than an equivalent cantilever spring and for many applications is more convenient than the more usual cylindrical tension and compression springs.

Such springs can be wound from wire, but this method is rather troublesome and is not very satisfactory, as the wire must necessarily be of uniform gauge, which means that the inner coils are too stiff and move solidly, all the deflection taking place at a few of the outer turns, while, the stiffness of the wire being the same in all directions, some independent guiding means must be provided to prevent its moving about too freely.

We use a number of these springs in our various products, and find that the best way of making them is to cut them out from sheet material, using one of our engraving machines. A suitable spiral is drawn out, say, ten times full size, and using this as a guide, a groove is cut out in a sheet of celluloid which serves as the master copy in the machine. By this

means it is as easy to work to the best theoretical outline as to any other, and, of course, the method is not restricted to cutting out such springs. It can be employed too for the economical



production from sheet of small quantities of instrument parts, where the number required would not warrant the cost of making press tools; or, indeed, the machine can be used to mill out the press tools themselves, working, of course, to an enlarged template, say, five or ten times full size.

THE TAYLOR-HOBSON RESEARCH LABORATORY, LEICESTER

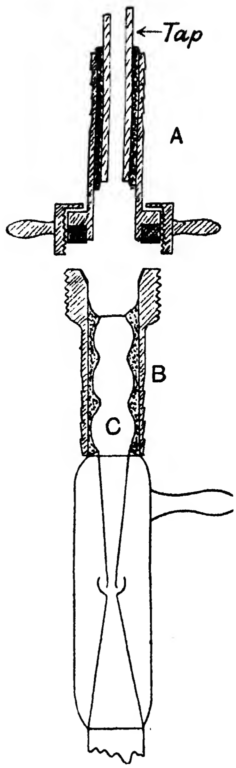
MIROIRS TRANSPARENTS. Par A. BIOT, docteur en sciences physiques.

Dans une note sur un procédé de collimation parue dans le numéro de décembre 1927 du *Journal*, M. le capitaine T. Y. Baker a montré les avantages d'inaltérabilité et de clarté que possède une lame plan-parallèle non argentée sur une surface recouverte d'une argenture transparente.

L'emploi d'une telle surface est cependant indiqué si l'on ne désire pas employer une lame dont les faces sont parallèles avec une haute précision, mais une lame ordinaire légèrement prismatique, et si l'on désire en même temps éliminer une des deux images que donne normalement une telle lame. On atteint ce résultat en réalisant une argenture transparente sur une des faces de la lame et en disposant cette lame de manière qu'elle reçoive sur la face argentée la lumière qui émane du collimateur. L'image donnée par l'autre face est alors pratiquement éliminée. Pour protéger la surface d'argent, il suffit de coller dessus une deuxième lame à faces planes. Mais il faut dans ce cas pousser suffisamment l'argenture pour que soit aussi éliminée l'image donnée par la face extérieure de la nouvelle lame. Ce n'est pas difficile à réaliser et les images restent en général très suffisamment lumineuses.

Remarquons encore que les propriétés des argentures transparentes varient avec le mode de production, et peuvent être remarquables au point de vue rendement. On lit par exemple, dans un travail de MM. Ch. Fabry et H. Buisson*, qu'une lame d'argent de 15 mμ d'épaisseur a comme pouvoirs de transmission et de réflexion respectivement 0·31 et 0·53, a qui assure une transmission de 0·16 après une réflexion et une transmission successives.

* *Journal de Physique*, 5e série, VIII, 1919, 189.



A FILTER-PUMP CONNECTION.

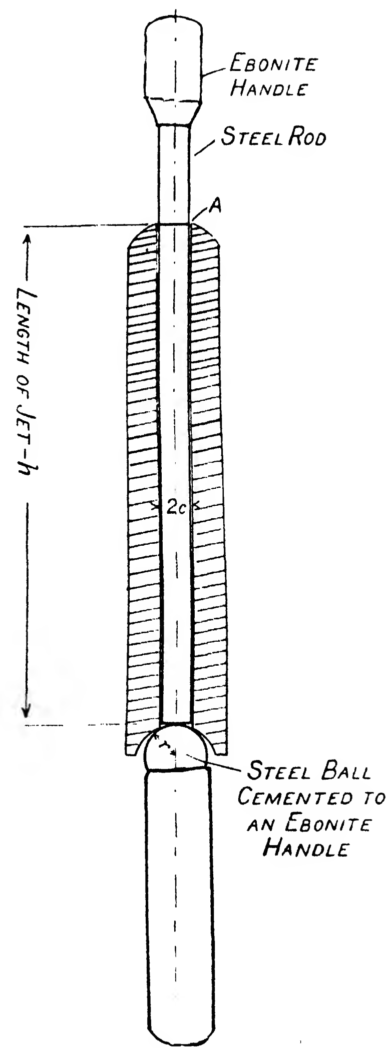
By R. C. BRIMLEY.

A few years ago it was found necessary to connect four or five glass filter-pumps to laboratory taps, where the water pressure was fairly high. The method adopted may be of use to others faced with the same difficulty.

An ordinary hose-connector is used, which can be obtained from most ironmongers. Referring to the diagram, the portion *A* is forced on to the tap with a short rubber-tube insert to make a tight joint. The connecting tubulure of the pump *C* is heated gently, and a plug of sealing-wax formed on it, of slightly greater diameter than the bore of the hose-connector. The portion *B* is then heated up till the plug slides into it slowly. On cooling, the wax forms a sound joint, and the hose-connector may be screwed up in the ordinary way. The only caution necessary is to heat the parts required to be joined till the wax runs on the hot surfaces.

If the pump chokes, or requires taking down for any other purpose, it only requires a minute or two to unscrew the connection, and screw it up again in the usual way.

I am indebted to Mr F. P. Slater, M.A., Head of the Experimental Department of the Fine Cotton Spinners and Doublers Association, Ltd., for permission to publish this note.



REDWOOD NO. 2 VISCOMETERS: A WORKSHOP METHOD OF CHECKING THE LENGTH OF JETS. By S. B. DICKINSON.

The fineness of the tolerance allowed, *i.e.* ± 0·02 mm., makes it necessary to have an accurate method of checking the length of the jet. Owing to the shape of the agate the usual workshop measuring instruments are not applicable. The method described here does not entail any calculations, when once the gauge has been made. It can be seen at a glance if the agate is within the tolerance allowed.

Using the formula $h = c^2/2r$, where

h = the depth of the segment of the steel ball that projects into the jet,

r = radius of the steel ball,

c = $\frac{1}{2}$ diameter of the bore of the jet,

a ring should be scribed round the steel rod, at A, 0·04 mm. wide. From the centre of the mark thus made to the end of the rod should be 50 mm. $-h$. This measurement may be made by means of a measuring microscope.

The diameter of the steel rod should be very nearly that of the bore of the jet.

REVIEWS

The Theory of Measurements. By LUCIUS TUTTLE and JOHN SATTERLY. London: Longmans, Green and Co. Price 12*s*. 6*d*. net.

The authors aim at providing science students generally with a course of instruction in the general principles and methods of measurement. It is intended that practical work shall form an integral part of the course, and details of experiments are given in the text. Each chapter is embellished with numerous exercises. The following selection of chapter headings gives an indication of the ground covered: Significant Figures; The Slide Rule; Graphic Representation; Interpolation and Extrapolation; Statistical Methods; Rejection of Doubtful Observations; Least Squares; Applications to Biology. The student is assumed to possess only rudimentary mathematical knowledge—elementary algebra but no trigonometry or calculus.

The book is well written in an easy style, the diagrams are clear, and care is taken that the terminology employed conforms to current statistical practice. In view of the limited mathematical equipment required of the reader, it is not surprising to find a number of formulae quoted without proof. The inclusion of the proofs, perhaps in small type or in an appendix, would have increased the value of the book to some students. A highly commendable feature is the care with which the elementary notions of statistics are explained and illustrated. In the final chapter, Applications to Biology, more difficult ideas are introduced than in the remainder of the book, and a fuller treatment of correlation, in particular, would be advantageous. W. S. S.

Electric Rectifiers and Valves. By A. GUNTHERSCHULZE, translated by N. A. de BRUYNE. London: Chapman and Hall, Ltd. Pp. x + 212. Price 15*s*. net.

This is a very comprehensive treatment of the large current rectifiers used in electrical power work, with a few references to the smaller rectifiers used in high frequency engineering. Mechanical, electrolytic, glow discharge and mercury vapour rectifiers are all dealt with in detail. The general arrangement is in two sections. In the first eight chapters the physical theory underlying the action of rectifiers is outlined, while the applications of the theory to actual power plant is given in the second section of nine chapters. The book contains such an enormous mass of information that it gives the impression of being unduly compressed. Much of the author's own research work is described, but references to detailed accounts are sometimes lacking.

The book is to be recommended as forming a useful contribution to our knowledge of a difficult subject written by an authority, but it is not an easy book to read.

It is quite obviously a translation from the German; the translator's theorem on the relation between clearness and elegance of style is not convincing. E. M.

Physics in Industry. Vol. v. Lectures delivered before the Institute of Physics. By H. E. WIMPERIS, O.B.E., M.A., F.R.AE.S., Director of Research, Air Ministry, and F. E. SMITH, C.B., C.B.E., D.SC., F.R.S., Director of Scientific Research, Admiralty. Oxford University Press. Pp. 54. Price. 2*s*. 6*d*. net.

The two lectures included in this volume are the tenth and eleventh of the series on Physics in Industry, and are well associated, as they both deal with the application of physics to the Services which has been such a prominent feature of the last decade. They are entitled "The Relationship of Physics to Aeronautical Science," and "Physics in Navigation" respectively, and are both of

great interest individually, as the former deals with the youngest and the latter with the oldest of our means of transportation. Aeronautical science is still in its infancy, and its very fundamentals still need an immense amount of research, while navigation is an old established science which only needs improvement in detail except for the one great problem of navigation in fog.

As would be expected, therefore, Mr Wimperis' lecture is almost exclusively concerned with the fundamentals of aerodynamics, and in short space it provides a remarkably clear summary of the present position of this important subject, which will be especially appreciated by the large number of physicists and engineers who have been unable to follow its detailed progress. The great difficulty which the aeronautical designer has been confronted with is the lack of a mathematical theory of motion in viscous fluids. While no scientifically based theory appears even yet to be on the horizon, immense assistance to the designer has been given in late years by the mathematical artifice of superposing a "circulation" on the ordinary stream line distribution for a non-viscous medium; and in the hands of Lanchester, Joukowsky and Prandtl formulae have been deduced for the forces on aerofoils of different forms, which have been found in many cases to be closely verified by experiment. The great value of wind channel tests on models is well known, but the results often have to be extrapolated tenfold or more to represent full-scale practice, owing to the small value of the Reynold's number which can be secured in ordinary wind channels. This number is the ratio of the product of length and velocity of the model to the kinematic coefficient of viscosity of the fluid, so that in order to make wind channel tests as directly comparable as possible with full scale experience the viscosity should be diminished in proportion to the length of the model. This can be done by increasing the pressure of the air in the channel, and a pressure channel operating at 20 atmospheres has recently been constructed at Washington.

Great interest will be felt in the description of the Cierva "Autogiro" and its performance. One of the remarkable results of the tests on this device is that its speed of vertical fall was only fifteen feet per second, or half that of a parachute having the same diameter and load. The lecture closes with a few remarks on aero engines and their special requirements; and the tests made with "tetra ethyl lead" and other additions to the fuel will interest all motorists.

In dealing with navigation Dr Smith had a wealth of historical experience to draw upon in addition to his own special knowledge of terrestrial magnetism and Naval problems. The lamentable delay in the development and application of science, due to the contempt of philosophers for experiment, is displayed to a high degree in the history of the magnetic compass, which was certainly known to the Chinese by the second century and to the Arabians in the thirteenth century, but received so little consideration that even as late as 1820 Barlow reported in favour of destroying half the compasses in the British Navy as being worse than useless. Barlow himself improved the compass by using a number of parallel magnets, but it was reserved for Lord Kelvin to apply the scientific principles of instrument design to it and to produce a type of compass which has persisted to this day. With the development of iron and steel ships, and especially of submarines with their enclosed hulls and heavy electrical equipment, however, the magnetic compass has ceased to be reliable, and the development of the gyro compass is one of the most brilliant achievements of scientific principles, experimental skill, and perfection of construction.

In view of the vital importance of navigation especially to this country, the slowness of the development of the compass is remarkable, but the record of the progress of position-finding at sea is not much less poor. It was not until the eighteenth century that Hadley invented the octant or sextant for the determination of latitude, although the crude astrolabes and cross staffs which had been employed for centuries must have pointed the way for more accurate instruments; and Harrison invented the chronometer for determining longitude. With these two instruments, and the publication of the Nautical Almanac, position-finding in clear weather became an accurate art.

The latter half of Dr Smith's lecture dealt with several of the recent devices for assisting navigation in fog and avoiding icebergs and other obstacles. Electrical logs have been largely employed for assisting the determination of position by dead reckoning, and in combination with the gyro compass have been used to actuate "course plotters," in which the course of the ship is automatically recorded on a chart. Depth sounding is a great aid to navigation and was greatly facilitated by the Kelvin sounding machine and tubes, but the acoustic devices developed by the Admiralty and others enable depths to be accurately determined at intervals of a few seconds with the ship at moderate or even full speed.

Position finding in thick weather has been rendered possible by acoustic and radio-acoustic

sound ranging, and by directional wireless, and the rotating wireless "beacon" promises to be a most valuable aid to navigation, as it enables ships to determine their bearing by a simple stop-watch reading.

The leader cable has proved to be a very successful method of following a definite course through a channel or into a harbour, and it is to be hoped that it will come into general use, although the initial cost and upkeep of the cable has been a deterrent to its adoption.

The problem of ice detection, which has always been a prominent one since the *Titanic* disaster of 1913, has unfortunately proved a somewhat intractable one. Soon after the disaster Mr L. F. Richardson suggested the employment of an underwater echo method, but experiments which have been made by Boyle and others have not given trustworthy echoes, largely due to the poor acoustic reflecting power of ice in water and to other disturbances. Attempts to locate the position of bergs by temperature measurements have also proved of little reliability, and the best protection seems to be afforded by the international patrol service inaugurated in 1914 and undertaken by the U.S.A.

The service of physics to navigation, great as it has been, is only a part of its total service to the Navy and mercantile marine, of which radio signalling alone would be sufficient to establish its vital importance, and there can be no doubt that it will rapidly extend. Few matters are closer to the British heart than the progress and safety of its Navy and maritime transport, and Dr Smith's lecture will be greatly appreciated by all who read it. The two lectures are a welcome and highly valuable addition to the series. C. V. D.

A Short History of Physics. By H. Buckley, M.Sc., F.Inst.P. London: Methuen and Co. Pp. 263. Price 7*s*. 6*d*. net.

In these days of intense specialisation and of large treatises and text books on special subjects, it is a refreshment to turn to wider fields, and Mr Buckley in this comparatively small volume has contrived to put the history of physics into a remarkably complete and readable form, which few will read without pleasure and profit. He has exercised a wise choice in the selection of such an enormous mass of material, and while stressing the most important features, has incorporated the minor ones in such a manner as to give an excellent connected idea of the progress of physics from the early Greeks to the present time.

The scientific historian usually finds himself in a dilemma between the frequently opposed requirements of chronological sequence and of the logical development of each branch of his subject, but Mr Buckley has contrived to reconcile them very harmoniously by his choice of subjects, as is shown by the headings of his fifteen chapters: Introductory; Planetary Theory; Mechanics and the Laws of Motion; Matter and the Conservation of Mass; The Corpuscular and Wave Theories of Light; Magnetism and Electricity; Heat and Thermodynamics; The Kinetic Theory of Matter; Radiation; The Atomic Theory of Electricity (two chapters); The Theory of Relativity; The Quantum Theory; and The Structure of the Atom. By this choice he has been able to follow the chronological sequence very closely, with little recapitulation or sacrifice of the scientific continuity of each section; and the whole history seems to develop naturally without any awkward halts.

Modern scientific investigation has become so specialized and intense that there are relatively few scientific workers who raise their eyes from their particular problems to the contemplation of science as a whole, and still fewer who follow the scientific method in their general outlook. This is an extremely serious matter, as science seems to be following the story of the Tower of Babel in erecting an enormous edifice by the labour of an army of wonderful builders, but without architects; and the result is visible in a confusion of tongues and a breach between science and humanity. The masses, while glad to accept and enjoy the material gifts of scientific work, have little knowledge of the aims and methods of science, and are indeed inclined to view them with suspicion, after the terrible results of scientific warfare and the immense progress of labour displacing machinery, which they regard as another weapon in the hands of the capitalists. On the other hand, scientific workers are being organized into a well drilled research army for conducting investigations according to instruction—Their's not to reason why!

For this reason a knowledge of the early history of science and of its struggles to establish truth against opposition should be an important part of the equipment of every scientific worker, and we are glad to see that Mr Buckley has devoted a fair amount of the first portion of his history to this

aspect, although he has greatly softened the opposition. But he has clearly brought out the differences between the Platonic or deductive school and the Aristotelian or experimental and inductive school, and also the spirit of lofty detachment from the problems of existence which seems to have been the besetting sin of philosophers from ancient Greece to modern Europe. With the Greeks, as with us, the most fascinating problems were the ultimate constitution of matter and the analysis of first causes; and ordinary humanity has had to feed on the crumbs or by-products of these investigations; which, although a wonderful gift, fall immeasurably short of the banquet which science could have provided had it kept in view its true rôle of "the saviour of humanity."

The modern physicist will, however, probably hurry over the earlier portions of the history to come to the later chapters in which the recent theories of relativity and of quanta are developed, and he will find much of interest in the clear and concise treatment of these subjects. As an intellectual achievement, these modern theories and investigations are certainly the crowning glory of the human mind; and in spite of many difficulties, we certainly seem to be rapidly approaching the goal of being able to interpret the whole of matter and its physical manifestations in terms of some single entity. Mr Buckley's history should meet with general appreciation, and it may be hoped that by the time a second edition is called for, he may be able to record a further great advance.

C. V. D.

CATALOGUE

We have received from the Askania-Werke A.G., Bambergwerk, Berlin-Friedenau, Kaiserallee 87/88, an interesting catalogue in English, ASTRO 80E, describing the Microphotometers of their manufacture.

The catalogue describes and illustrates the Hartmann microphotometer, in the three forms in which it is made, developed by Dr J. Hartmann for the photographic measurement of the surface illumination of stellar bodies and of their spectra. The photo-electric instrument of Rosenberg is described, and also the photographic recording microphotometer of Dr P. P. Koch.

NOTICES

THE EFFECT OF LIGHTING ON OUTPUT AND ACCURACY

His Majesty's Stationery Office announce the publication of a report on "The Effect of Different Systems of Lighting on Output and Accuracy in Fine Work (Type-setting by Hand)" which, although not primarily concerned with lighting in relation to instrument use or manufacture, may be of interest to readers of this *Journal*, since it has an obvious bearing on work of this nature.

This Joint Report of the Illumination Committee of the Department of Scientific and Industrial Research and the Industrial Fatigue Research Board deals with the results of an investigation to discover the *system* of lighting best calculated to secure the comfort and efficiency (both as regards output and accuracy) of workers engaged in hand composing in letterpress printing, and supplements the previous investigation (upon which a similar Joint Report was issued in October, 1926), the object of which was to discover the *amount* of illumination desirable to secure these ends.

In the experiments now described, the effect of different installations in common use has been studied, the actual illumination being kept constant.

The results here given, taken in conjunction with those in the previous Report, indicate the lines upon which an installation should be planned in order to obtain the best results for such work as that carried on in composing rooms. Full-scale trials upon the lines indicated, made under ordinary working conditions, should have every expectation of success.

The cost of the Report is 4*d*. net, postage extra.

DEVELOPMENT OF STANDARDIZATION AND SIMPLIFICATION

We have received from the Board of Trade a report of a meeting held on March 8th, 1928, at which the President of the Board of Trade (Sir Philip Cunliffe-Lister) presided, to consider means for the further development of standardization and simplification. There were present representatives of the Federation of British Industries, the British Engineering Standards Association, the British Electrical and Allied Manufacturers Association and a number of other important industrial organizations.

The President recalled the resolution passed at the Imperial Conference in 1926, in favour of the further development of standardization and of Imperial co-operation for the purpose. Before this country was in a position to participate effectively in an inter-Imperial movement, however, further progress must be made here. With regard to standardization proper it was, of course, most desirable that the valuable work conducted by the British Engineering Standards Association should be continued and developed by that body. At the same time it was felt that the movement could be extended with great advantage to other industries, and that some central organization was necessary to assist the work and to bring its advantages to the notice of particular industries.

The subsequent discussion showed a general agreement as to the importance of developing standardization and simplification further than the movement had yet gone in this country, and as to the necessity of having some central organization of the kind suggested. The meeting requested that a representative of the Board of Trade should act as Chairman of the proposed body. It was accordingly decided to set up a Committee under the chairmanship of Mr Herbert Williams, M.P., consisting in the first instance of the representatives of the Associations attending the meeting, together with representatives of government departments concerned. The first meeting of the new body was fixed for March 27th.

NOTICE TO SCIENTIFIC INSTRUMENT MANUFACTURERS

In order to keep readers of the *Journal* in touch with the latest developments in scientific instruments, the Editor would be glad if all manufacturers of such instruments would keep him informed of all new instruments or important improvements in their productions as soon as they appear, either by sending him catalogues, pamphlets, or circulars concerning them, or in the case of important developments, by letting him have concise special descriptions of their construction and performance. Descriptions of light machine tools suitable for instrument work would also be appreciated.

LABORATORY AND WORKSHOP NOTES

Readers of the *Journal* are reminded that notes concerning laboratory or test-room methods, and workshop devices or methods of utility to instrument-makers are welcomed, and that ten shillings will be paid for each such note published.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V MAY, 1928 No. 5

A MODERN PHOTOGRAPHIC ELECTROGRAPH.

By R. E. WATSON, B.Sc., Ph.D. Kew Observatory.

[*MS. received, 24th January*, 1928.]

ABSTRACT. The article describes a new installation for obtaining continuous photographic records of atmospheric electrical potential, in which, owing to the unique construction of the insulators, uncertainties due to defective insulation are reduced to a negligible amount. The capacity of the system is small, and rapid changes of potential are well registered, while the sensitiveness is capable of variation through fairly wide limits.

Introduction

The apparatus has been constructed by the Cambridge Instrument Company, Ltd., for the Royal Alfred Observatory, Mauritius, and the following notes on its construction and behaviour are the result of tests carried out at Kew Observatory, Richmond. Most of the instrumental troubles with recording electrographs arise from defective insulation due to moisture condensing on exposed surfaces of the insulators, and the avoidance of such condensation is the guiding principle in the design of any new instrument. Spiders cause troublesome failures of insulation by short-circuiting the insulators with webs, but the effect is not fundamental; the webs are easily removed and unless they are moist they are non-conductive. The climate of Mauritius is particularly humid; thus, when it was decided to instal an electrograph there, it was necessary to take special precautions to ensure prospects of satisfactory operation, and Dr G. C. Simpson, Director of the Meteorological Office, was consulted. He collaborated with the makers and designed some unique insulating arrangements which have proved almost ideal, making the apparatus one of the best of its kind for universal use.

Description of Installation

The outfit as a whole is shown in the sketch, Fig. 1, which indicates the relative positions of the parts of the apparatus when in operation in the recording hut. It consists of three particular parts: *A*, the radio-active collecting arrangement (Fig. 2); *B*, the recording electrometer (Fig. 3); and *C*, the recording camera (Fig. 4).

The collector itself, *S*, Fig. 2, is a copper spiral about 2 in. long, coated with radium bromide and varnished to make it weather-proof, of the type usually supplied by the late Mr Harrison Glew. When actually in use the long boom of the collecting arrangement passes, without touching, through a hole in the side of the building to expose the radio-active collector to the outside air. In the photograph the spiral is shown inside a glass covering cap which serves to protect the spiral when not in use; the cover is removed when

the spiral is brought into action. The radio-active collector screws on the end of a tapering screw-jointed metal boom about 5 ft. long, which is carried by two supports P and P attached to the boom insulators. The wooden box which houses the boom insulators is generally

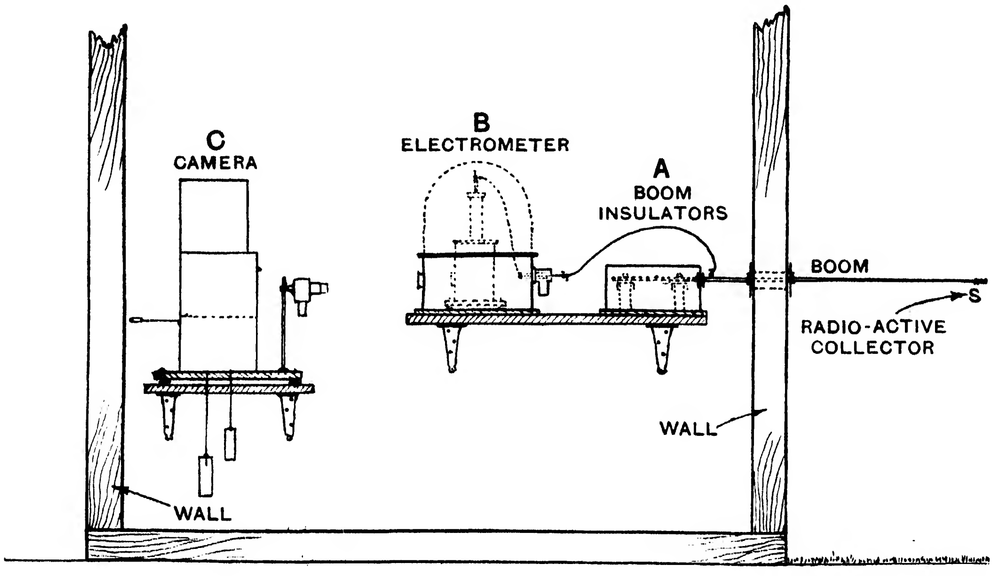


Fig. 1

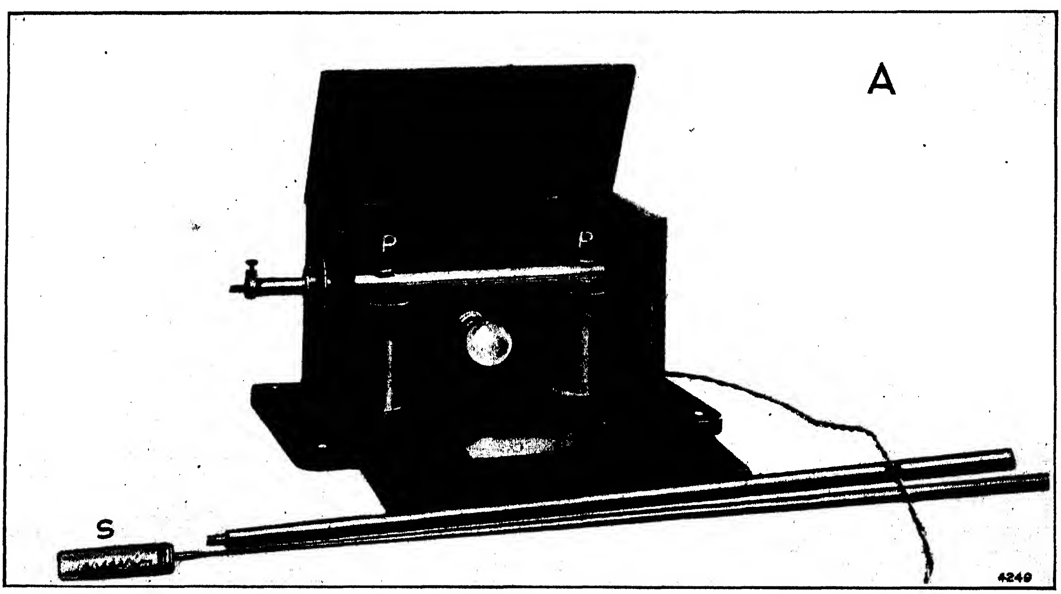


Fig. 2

set up near the hole in the wall communicating with the outside air, and special protection against the moist outside air is essential. The construction of the insulators is shown in detail in Fig. 5.

Each insulator consists of a metal cylinder D, having a drilled base for attachment to the containing box. In order to insulate it, the support P is embedded in sulphur (being fixed in position when the sulphur is molten) so as to protrude about 1 in. above the surface.

This protruding portion is screw-threaded, and a cylindrical metal cover *E*, of slightly larger diameter than the cylinder, is screwed down *P* over the sulphur so as just to clear the containing cylinder. In this way a narrow air gap is provided around the top of the cylinder and the exposed sulphur surface, thus preventing ingress of moist air, and the consequent condensation of moisture on the exposed surface. The lower end of *P* is splayed to prevent it rotating in the sulphur, and two or three screws are bored into the base of the sulphur to prevent it rotating in its cylinder. The boom is adjusted and rigidly fixed to the supports *P* and *P* by screw nuts. The insulators are housed in a wooden box with suitably hinged side and top, which can be screwed down firmly in any desired position. The boom

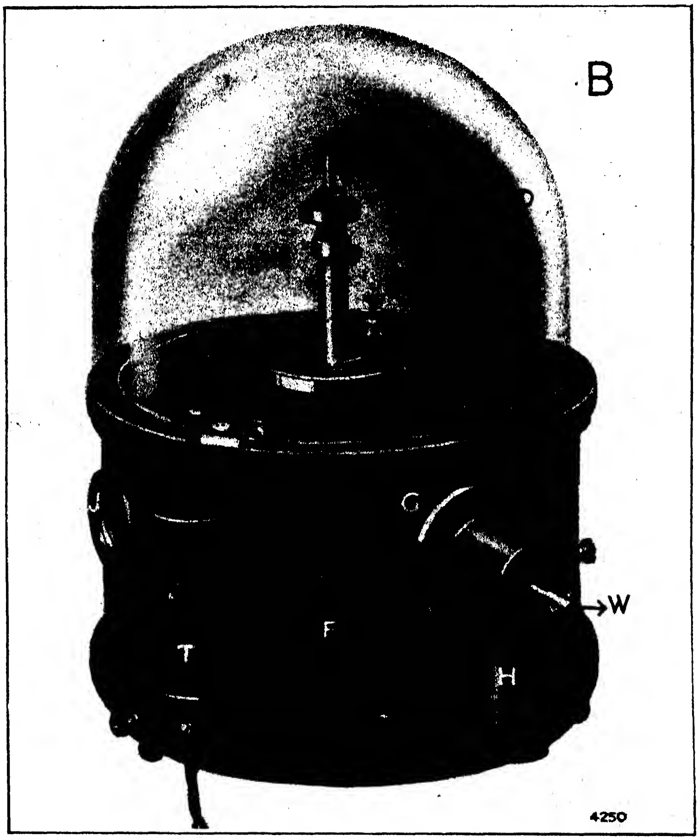


Fig. 3

passes with plenty of clearance through a hole at one end of the box and then through a hole in the side of the building. To exclude the outside air and so assist in keeping the air inside the box as dry as possible, adjustable baffle plates, *K* and *K'*, Fig. 5, are fitted on the boom on either side of the holes so as just to clear the adjacent surfaces. A 4–volt, 12 watt electric lamp fitted inside the box serves to keep the insulators warm and dry in any kind of weather.

The height of the radio-active collector above ground and its distance from the building regulate the magnitude of the potential "picked-up" in the air.

The recording electrometer *B*, Fig. 3, is the usual pattern Dolezalek electrometer except that the torsion head is supported by an amber instead of an ebonite insulator. It stands in a hole, slot and groove arrangement on a circular metal plate with a grooved rim, into which fits a cylindrical case *F*, about 12 in. diameter and 8 in. high. This case is also grooved at

the top to accommodate a hemi-spherical glass cover *D*. In the photograph, Fig. 3, the wire which connects the needle of the electrometer (via the terminal in the torsion head), to the "lead-in" wire *W*, is not shown. Both grooves are filled with chemically pure vaseline to provide a moisture-proof seal between the cases. The interior of the case and the electrometer are kept warm and dry by means of a screened 4-volt, 12 watt lamp, which maintains the temperature inside the case about 5° F. above that of the outside air. A special insulator was designed for carrying the "lead-in" wire through the case from the boom to the electrometer; its construction is shown in detail in Fig. 6.

The "lead-in" wire *W* is mounted on a long amber plug *V* which screws into the metal case *F* and is surrounded by a cylindrical baffle shield which slides on *W* so as just to clear the metal case *F*. This shield is further enclosed in a cylindrical cover *G*, having a bayonet-jointed rim for fixing it firmly to the side of the case *F*. A small hole *Q* in the end of the cover *G*, slightly greater in diameter than the "lead-in" wire, allows for the passage of the "lead-in" wire, and the small air gap between the wire and the hole *Q* is the only entrance for air from outside to the insulating plug. A downward extension *H* of the outer cover contains a screened 4-volt, 12 watt electric lamp which keeps the insulating plug warm and dry in any kind of weather. As a further aid a small tray containing a drying agent can be placed inside the cover *G* for drying the insulator.

A glass window *J*, shown in Fig. 3, in the outer metal case allows the passage of the recording beam of light to and from the electrometer.

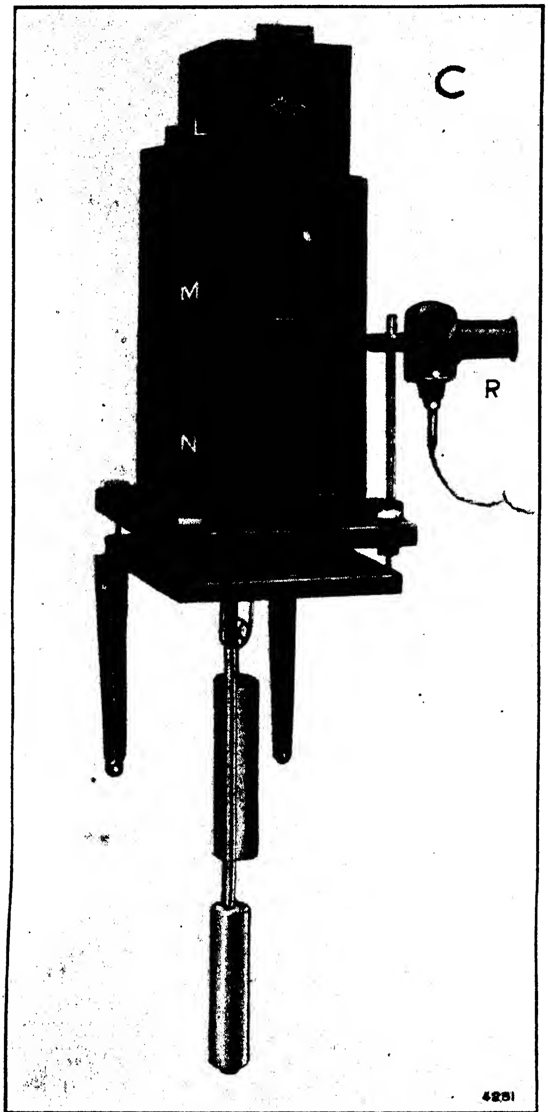


Fig. 4

Two needles or vanes are supplied with the electrometer, a flat metal one and a split silvered paper one, and the potential is carried through the torsion head to the needle by a fine phosphor bronze strip suspension. The quadrant potentials are provided by a battery of six standard Weston cells (the mid-point of which is earthed), fitted neatly inside the metal case *F*, instead of outside as usually happens. In this way additional insulating plugs through the case are avoided, and the risks of adversely affecting the insulation of the system considerably reduced. Separate terminals are provided on each cell so that the quadrants may be connected to + 1 and − 1, + 2 and − 2, + 3 and − 3 cells respectively. Suitable high resistances are inserted between the cells and the quadrants to prevent damage to the cells in case of a short circuit across the quadrants.

The recording camera *C*, Fig. 4, consists of three cubical compartments *L*, *M* and *N*, about 9 in. side, built one above the other on a metal base provided with levelling screws and clamps. An adjustable electric lamp *R*, sliding on a vertical rod in front of the camera, illuminates a vertical slit cut in its containing case. The image of the slit reflected from the electrometer mirror is then made to fall on the hemi-cylindrical lens of the camera, when it is condensed to a "dot" of light on the photographic paper in a position corresponding to the potential on the electrometer needle. The photographic paper is drawn from a roll in the top box, in a continuous band, into the middle box, where it passes over a roller behind the hemi-cylindrical lens, then through propelling rollers into the lower collecting box. It is driven by an 8-day, seconds-pendulum clock with a heavy weight which maintains a uniform rate of supply of paper. The top box *L* has a sliding side to enable fresh rolls of paper to be fitted and the middle box *M* has a hinged door giving access to the hemi-cylindrical lens

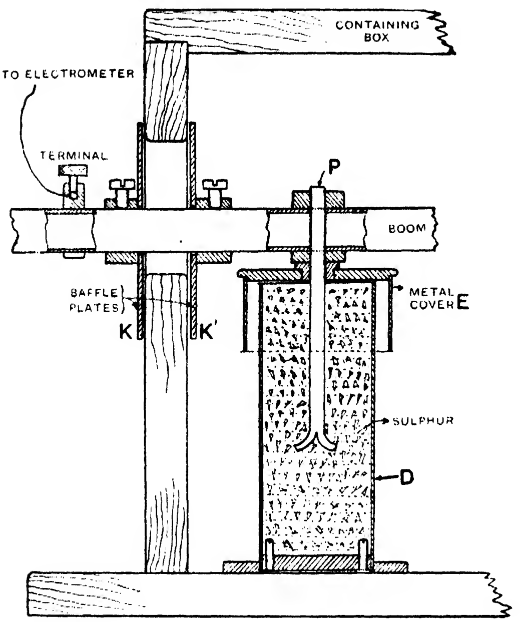


Fig. 5

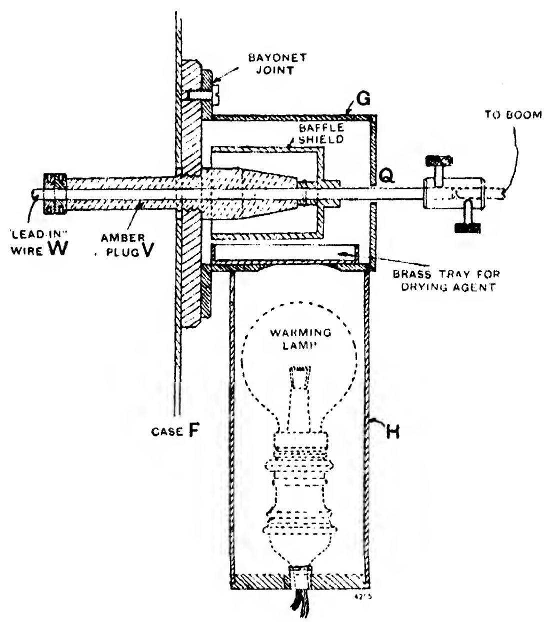


Fig. 6

and to the propelling rollers connected to the clock. The bottom box *N* is removable from the casing and has a sliding brass lid which is withdrawn against a stop when the paper is feeding. When the lid is pushed in it cuts off and encloses the exposed chart in the box, which is then light-tight, and can be removed to the dark-room for development of the chart.

A horizontal shutter with a white centimetre scale marked on it can be turned upwards over the opening to the camera lens for rapid eye-reading determinations of the scale value and insulation value. It is useful in standardizing the apparatus without the delay necessary to the development of the record when these tests are carried out photographically for permanency.

Time marks are made photographically every hour by means of a lamp *T*, Fig. 3 (hung on the metal case *F*), which is connected through a relay to the hour contacts of a master clock. A horizontal slit is cut in the case of the lamp, and made to face the camera; thus for a few seconds at every exact hour a beam of light is projected across the whole width of the camera lens, and produces a fine black line across the developed record.

Some Results of Examination

Although the tests were carried out in wet misty weather in the autumn, in a hut, in the middle of a paddock, without the use of any heating arrangements beyond those fitted to the installation, no breakdown of the insulation occurred. Insulation tests were carried out each morning, often after wet nights, and the following typical eye-reading observation of the rate of leak of the whole apparatus (minus the radio-active collector) indicates the excellence of the insulating arrangements:

Time (minutes)	0	½	1	1½	2	2½	3
Voltage during leak	158	158	158	157	156	156	156

The double period of oscillation of the metal and silvered-paper vanes is about the same, approximately 7·5 seconds, but the paper vane damps down to rest in about two-thirds the time of the metal vane and is the more suitable for photographic registration.

The photographic paper is 15 cm. wide, and the scale of the electrometer, which must be set up 1 metre from the camera, is linear across the width of the paper. With the metal vane, and the quadrants connected to + 1 and − 1 cells respectively, the scale value of the record is 14·3 volts per centimetre, while with the paper vane under the same conditions the scale value is 16·3 volts per centimetre.

As a collector of atmospheric electricity in all weather conditions a radio-active spiral is not as rapid as a water-jet, but the capacity of the Cambridge Instrument Company's electrograph is so small compared with that of the Kelvin water-dropper, with its large reservoir of water, that the installation as a whole is as efficient in operation in this respect as the water-dropper, as shown by the following figures:

Comparison of Rates of "Picking-up"

							½ min.
Time (seconds)	0	5	10	15	20	25	30
Volts: Kew water-dropper...	0	42	96	146	172	200	220
Cambridge Inst. Co.'s electrograph	0	48	116	164	215	249	282
						1 min.	
Time (seconds)	35	40	45	50	55	60	
Volts: Kew water-dropper...	240	253	264	274	280	285	
Cambridge Inst. Co.'s electrograph	309	332	350	371	383	389	
						1½ min.	
Time (seconds)	65	70	75	80	85	90	
Volts: Kew water-dropper...	288	289	293	294	295	295	
Cambridge Inst. Co.'s electrograph	396	399	401	401	398	—	

Each electrograph system reaches the normal potential of the air in which it is situated, from zero, in about 1 minute. The potential is "picked-up" according to an exponential law, the logarithmic decrements of the two instruments being ·051 for the Kelvin water-dropper, and ·047 for the Cambridge instrument (using natural logarithms, and the time interval $t = 1$ second).

The mean hourly values of the potential gradient for the day, as recorded by the Cambridge Instrument Company's electrograph, were compared with those from the Kew Kelvin water-dropper over several days in October. The values obtained are given below, and shown graphically in Fig. 7. The results from both instruments have been converted to volts per metre in the open, by the application of appropriate "exposure factors" obtained from the same absolute observations of potential gradient in the open. They are rounded off to the nearest 5 volts per metre:

Comparison of Mean Daily Potential Gradient

Hour	0 (Midnight)	1	2	3	4	5	6	7	8	9	10	11	12 (Noon)
Kew water-dropper v/m	310	275	280	215	225	270	245	280	250	395	405	415	445
Cambridge Inst. Co.'s electrograph v/m	330	285	265	210	215	270	250	285	260	405	410	415	435

Hour	13	14	15	16	17	18	19	20	21	22	23	24 (Midnight)
Kew water-dropper v/m	495	470	435	470	465	440	460	415	380	270	340	310
Cambridge Inst. Co.'s electrograph v/m	485	460	425	455	455	455	460	435	395	270	365	330

Kew water-dropper ... ... Daily mean = 362 v/m; Daily range = 280 v/m.
Cambridge Inst. Co.'s electrograph Daily mean = 364 v/m; Daily range = 275 v/m.

For all practical purposes the daily means and daily ranges are equal.

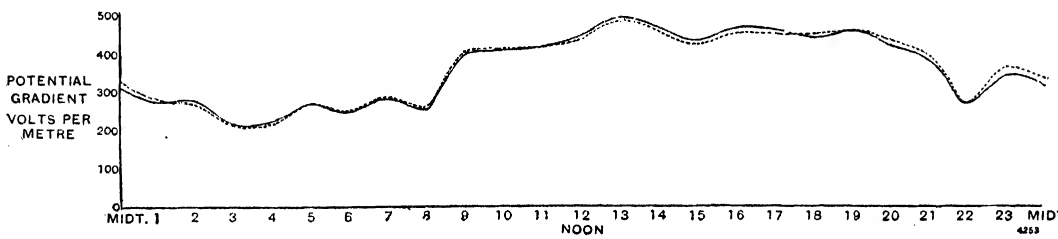


Fig. 7

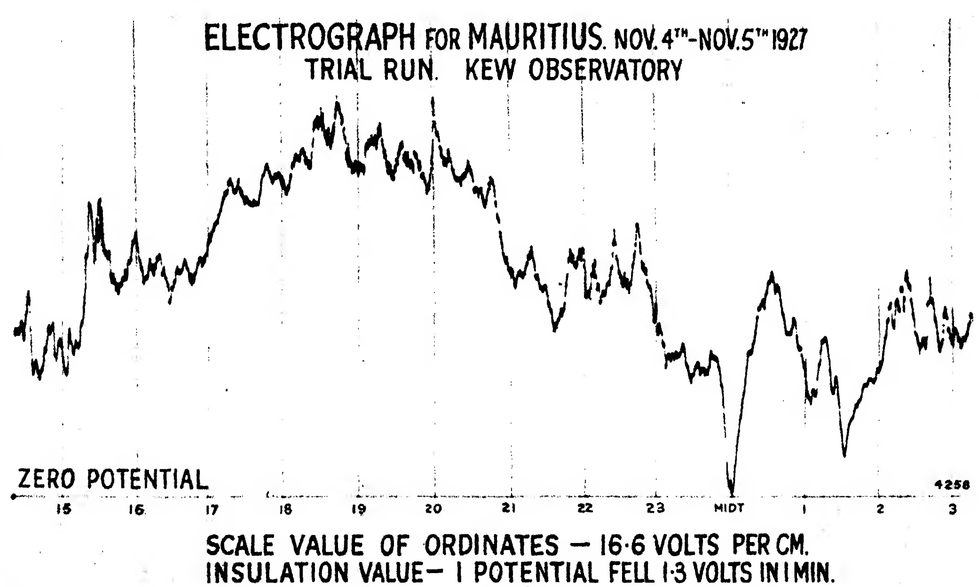


Fig. 8

Considering the diversity of the time scales and the scale values of the two instruments (which affect the percentage error in the measurement of the curves) and the fact that there were large oscillations in the potential gradient during the selected period, which was wet

and misty throughout, the mean hourly values registered by the Cambridge Instrument Company's electrograph are in strikingly close agreement with those from the Kew standard electrograph. This in itself is a convincing proof of the superior quality of the insulating arrangements on the new electrograph, and stamps it as a satisfactory recorder of atmospheric potential gradient.

A specimen trace obtained at Kew is reproduced above, two-thirds the actual size (Fig. 8). It indicates the general "liveliness" of the electrograph under the working conditions enumerated on the chart. "The voltage recorded on the chart rose from a mean hourly value of 55 volts at 15 h. on November 4th to a maximum of 115 volts at 19 h., the usual time of the daily maximum at Kew. It then fell to 45 volts at 1 h. on Nov. 5th. To give the corresponding potential gradient readings in volts per metre in the open, the above values should be multiplied by 4·0, the 'exposure factor' of the instrument. The weather was cloudy during the night in question and the sharp rise and fall in voltage about midnight was probably due to the passage of a large cloud over the observatory."

ON THE "MISTUNING" OF WEIGHTED FORKS. By

WALTER R. MILES, Ph.D. Professor of Experimental Psychology, Stanford University, California.

[*MS. received, 6th March*, 1928.]

ABSTRACT. Weighted tuning-forks in general use are so constructed that the weights cannot be adjusted with very great exactness. The question is raised whether an important error is apt to result. Photographic records are submitted which show the vibrations from *both prongs* when the weights have been unequally set. Variations between the settings of the two prongs as large as 22 v.d. were tried. The prongs always vibrate alike so far as rate is concerned. The "slower" prong appears to show the smaller amplitude. The change from unequal weighting, or unbalancing the fork, is shown conspicuously in the duration of the tone. Precise tuning may be done by shifting one weight. Four prongs, as arranged on a farmer's pitchfork, vibrating together, demonstrate beats and behave differently from the members of the tuning-fork.

Weighting the prongs of tuning-forks serves (*a*) to secure low tones from forks of relatively small dimensions; (*b*) to increase the amplitude of vibration (of importance if the fork is to be used as an interrupter in an electric circuit); (*c*) to intensify the tone volume when the fork is presented to the ear or before a resonator; and (*d*) to make possible different vibration frequencies from the same unit. The advantages are so considerable that weighted forks are very commonly employed in all kinds of laboratories.

The weighting loads on the prongs must, in the nature of the case, be securely fastened by screws, locknuts or some other equivalent means, so that during vibration there will be no rattling. It is not practical to have the weights adjusted by a micrometer arrangement; and, hence, when the loads are shifted in order to change the frequency there is always a question as to the accuracy of adjustment of the two prongs. An electrically-maintained tuning-fork described by Wood and Ford (1) is said to be capable of being set with an accuracy of 0·1 mm., but most weighted forks are hardly set closer than 0·5 mm. Is this an important error? The records presented are offered in answer.

Some time ago I made a number of photographic records showing the vibration of *both prongs* of forks that had been deliberately "mistuned." The records were made to demonstrate to university students that no matter how the weights were arranged, both prongs

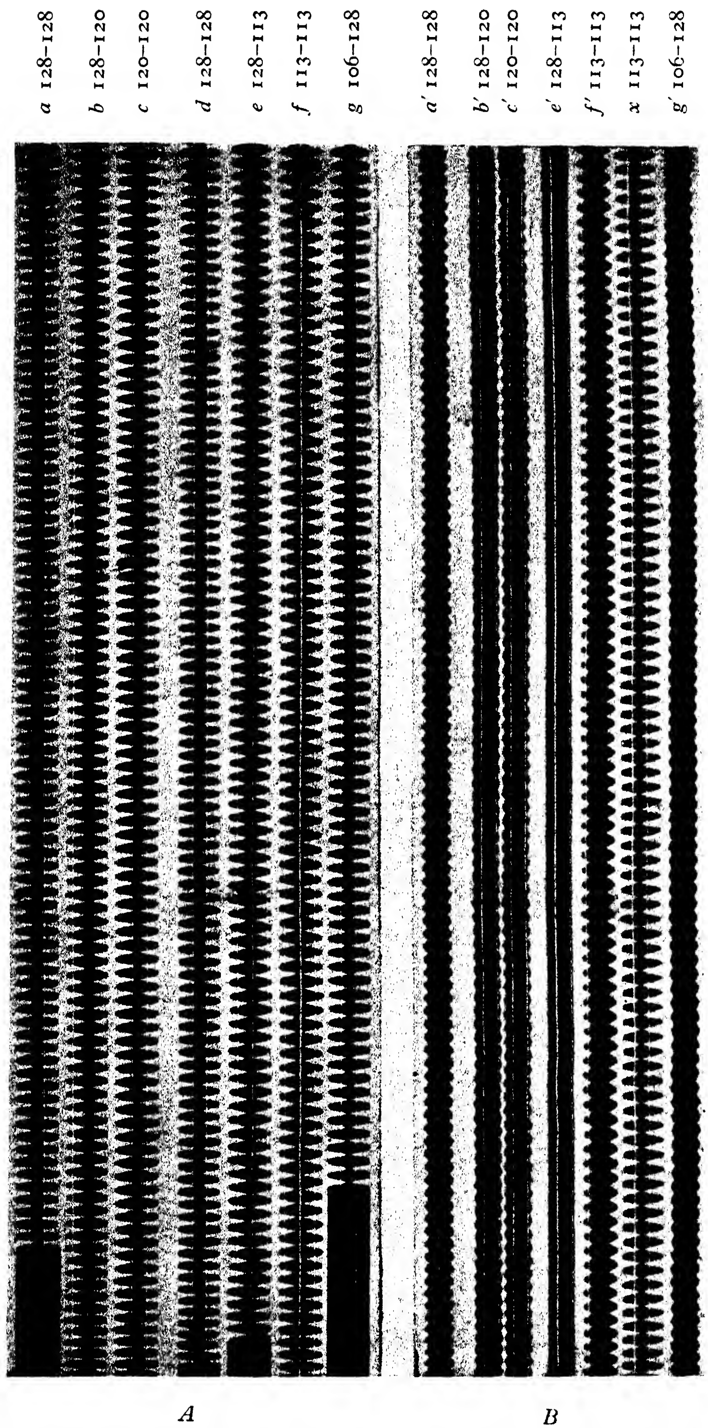


Fig. 1. Two-prong records made from "mistuning" a heavy fork with sliding weights. *A* covers about the first 0·5 second of vibration, and *B* a similar period after the fork has been sounding for 5 seconds

[*To face p.* 152

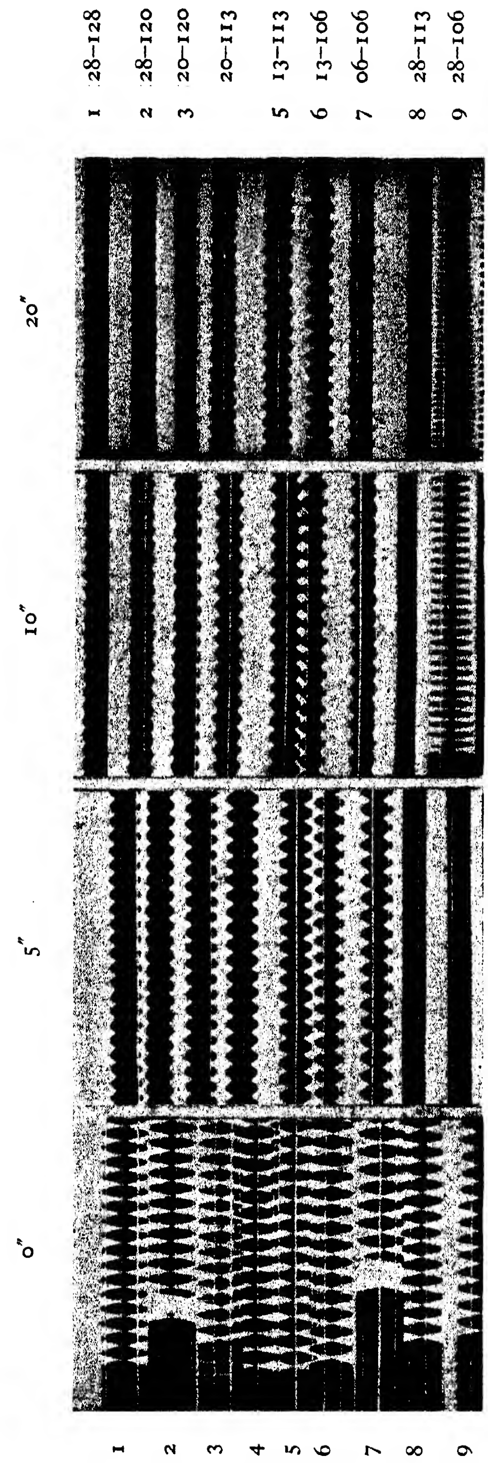


Fig. 2. Records showing the sustaining power of the tuning-fork when the prongs are variously weighted

would give the same pitch. In listening to the tone from a fork that has its weights unequally placed, observers fail to hear any difference when first one prong and then the other is held near the ear. When told to listen for beats they can hear none. Nevertheless, the query as to the true condition remains in the observers' minds and can only be satisfied by such visible records as photographic plates can give. A recent perusal of the notes in this *Journal* by Mason (2), Wood (3) and Dye (4) caused me to hunt up the series of records made at Wesleyan University in 1914, two sets of which are here reproduced.

The forks examined and photographed were mounted in a perpendicular position on a medium weight, adjustable clamp-stand so that the prongs would cast shadows across the horizontal slit of a Dodge (5) falling-plate camera. The slit was fitted with a cylindrical lens and the rate of fall used was about 216 mm. per second. The optical system and apparatus was that used in electrocardiography. The forks were about 4 in. away from the camera and the stand was moved to successive positions parallel with the slit so as to take several records side by side on the same plate. A small paper flag attached to one prong and extending toward the other, parallel to the plane of motion, at the level of the camera slit, brought the movement of the two prongs into close proximity. The light passed between the prongs when a record was made, and exposed a strip about 6 mm. wide.

A fork was energized by the sudden withdrawal of a wooden wedge from between the prongs. Care was used to energize the prongs equally for each trial. The forks were not touched by the hands and ordinary precautions were taken in reference to temperature changes. Time lines, 100 per second, were inscribed by a 50 v.d. wide-amplitude vibrating finger placed in the path of light. The thin vertical lines on the records are shadows cast by etched rulings on the cylindrical lens.

The fork from which our records were made had heavy parallel prongs, not quite square and about 20 cm. long, and the sliding weights, which were square and surrounded the fork prongs, could be so shifted as to cover the range from 106 to 128 v.d.

The sample records reproduced in Fig. 1, *A* and *B*, represent 14 recordings. The dark portions are the individual records and are to be read from the bottom upwards. At the bottom of *A*, it will be seen that the wedge was not withdrawn at just the same place in the fall of the plate for each trial. Photograph *A* represents somewhat more than the first 0·5 second for the fork as used in the different settings. For record *a*, the left-hand prong was set at 128 v.d. and the right-hand prong at 128 v.d. Stating the settings thus from left to right, and for the different trials, they were as follows: *b*, 128 and 120; *c*, 120 and 120; *d*, 128 and 128; *e*, 128 and 113; *f*, 113 and 113; and *g*, 106 and 128 v.d. It is at once obvious that both prongs of the fork vibrate at the same rate in every case, although in three instances one of the prongs had been weighted to vibrate at a considerably slower rate than the other. The actual rate disclosed by the photographs is very near an average for the settings as shown on the prongs. For *a*, it is 116·8 v.d., for *c*, 120·4, and for *f*, 124·2 v.d. Thus there were two records, *c* and *e*, in which the fork's rate was 120·4; in one instance both prongs had been set at 120, while in the other one prong was set at 128 and the other at 113 v.d. For a tone of brief duration, one of these settings is apparently as good as the other.

The vibration amplitude during the first half-second or more is practically the same for all combinations of weighting. The amplitude in this instance was determined at the start by the deflection of the prongs with the same wooden wedge for all trials, and the tones do not die away immediately. There is, however, some difference between the amplitudes of the two prongs when they have different weighting. The one that is weighted to vibrate at the slower rate presents a lesser amplitude. Our set-up was not well arranged to measure this with suitable exactness.

Representing the duration of the tones we have photograph *B* of Fig. 1, and the sections from four photographs taken at the intervals 0, 5, 10, and 20 seconds which constitute Fig. 2.

In *B*, we have records taken 5 seconds after the fork had been set in vibration. The series of weight settings recorded in *A* is substantially repeated in *B*. Records a', b', and c' all show the fork in motion, but the amplitude is less in b' where the difference in weight position is 8 v.d. Record e', where the difference is 15 v.d., shows the fork motionless. Records f' and x are both of 113–113 v.d. The latter was recorded immediately after the tone started, whereas f' came 5 seconds after a sounding. The two are recorded side by side for comparison of vibration amplitude and as a check on the constancy in rate of fall of the Dodge camera. Trace g' is with the prongs set at 106–128, a difference of 22. In Fig. 2, record 9 (the 5″ section), the combination is shown to have ceased sounding by the time the record was made. I cannot explain the difference between the two records. In the sections for 10″ and 20″ intervals, combination 9 was sounded afresh and the fall of the plate was set to a slow rate to show the rapid decline in vibration amplitude. The pitch rate for the prongs in this case is 116·8 v.d. The other records in Fig. 2 show that where the difference between the positions of the weights is 7 or 8 v.d. the fork will continue to vibrate appreciably for 20 seconds or more. When forks are presented to the ear or before a resonator, 20 seconds is long enough for most purposes of judgment or comparison; as a matter of fact, 5 seconds is usually sufficient.

These tests demonstrate that the term "mistuning" can be rightfully used in only a very limited sense in reference to weighted forks. It is really "unbalancing" that we are speaking of in this case, since no matter how unevenly the weights are set, so long as there is a tone at all, that tone will be the same from each prong. If the weighting is so unequal that the antinode is shifted outside the fork's handle or stem the fork will have poor sustaining power but otherwise its tone for short intervals will be satisfactory to the ear. We may derive from these results the very practical rule that in tuning a fork to a very specific rate, for example, in connexion with running a phonic-motor chronograph or timer, when we get near the desired rate the regulation may be completed by adjusting only one weight.

To those who are interested in the tuning-fork there is another fork, the ordinary four-tined variety used by the farmer, that may be recommended as an attractive object for vibration study. If two prongs are vigorously plucked, all four will be set in vibration, but ordinarily it will be observed that the amplitudes differ somewhat and that one prong periodically comes to rest, a thing never observed in a two-pronged tuning-fork. Beats can be heard from the pitchfork when all four prongs are vibrating, or if one is held and three are allowed to vibrate. If two are held tightly and the other two plucked, it matters not which combination of two is used, whether alternate or adjacent, the prongs will vibrate as a tuning-fork vibrates and no beats will be heard nor evidence of beats seen. One prong will not sound alone when three prongs are held. Therefore, "mistuning" does apply to the tones produced if there are more than two prongs mounted firmly together. In this case the node for a single prong appears to have a relatively fixed position.

REFERENCES

(1) A. B. Wood and J. M. Ford, "The phonic chronometer," *Journ. Scient. Instr.* **1** (March, 1924) 161–173. See Fig. 4.

(2) C. C. Mason, "Note on tuning-forks," *Journ. Scient. Instr.* **1** (May, 1924) 250–251.

(3) A. B. Wood, "Electrically-maintained tuning-forks. Some factors affecting frequency," *Journ. Scient. Instr.* **1** (August, 1924) 330–339.

(4) D. W. Dye, "Note on electrically-maintained tuning-forks," *Journ. Scient. Instr.* **1** (August, 1924) 340–341.

(5) Dodge and Benedict, "Psychological Effects of Alcohol," *Carnegie Institution of Washington*, Pub. No. 232, 1915, Section on Recording Camera, pp. 79–80.

LABORATORY MEASUREMENT OF CAPACITY, POWER FACTOR, DIELECTRIC CONSTANT, INDUCTANCE AND RESISTANCE, BY USE OF THE SERIES RESISTANCE BRIDGE. By CLAUDE L. LYONS, M.Inst.R.E.

[*MS. received*, 30*th November*, 1927.]

ABSTRACT. For precise measurements of small capacities, or for the accurate determination of dielectric losses, as well as for several other purposes, the ordinary form of bridge is rather unsatisfactory, since frequently the stray capacities are of the same order of magnitude as those under measurement. A more satisfactory form of "capacity bridge," incorporating the complete shielding of its elements, is described. The instrument, which is a modified form of Wiens' series resistance bridge, is designed for general use in the radio and electrical laboratory.

A survey is given of auxiliary equipment necessary to form an efficient laboratory "set-up" of the instrument, including such items as a cheap and efficient "source" of A.C. of fixed frequency and reasonably satisfactory wave-form. The use, and the schematic circuit of an auxiliary vacuum tube amplifier of the tuned audio-frequency type is shown, the purpose of which is to increase the overall efficiency of the apparatus and to assist in the more accurate determination of the exact balance point of the bridge.

The general operations, and formulae for the precise measurement of fixed and variable capacities are given, as well as for the determination of power factor, phase angle, dielectric constant (including change of this constant with variation in temperature) and the ascertainment of small and large resistances and inductances. Whilst the data given refers to the described bridge in particular, the methods may very easily be applied in regard to series resistance bridges in general, as well as to some other forms.

It is very doubtful if there exists in the radio research laboratory a more useful piece of apparatus than a well-designed "capacity bridge." Its uses are manifold. It may be used effectively to measure capacities from as small as a fraction of a microfarad to capacities as high as a farad. It makes possible the accurate ascertainment of the true capacity and power factor of condensers, whether variable or fixed. Inductances and resistance values may also speedily be measured.

The Capacity Bridge about to be described in this article is a modified form of Wiens' Series Resistance Bridge. It is a commercial instrument, built with considerable precision, yet sturdy enough to withstand laboratory handling or continuous use, day after day, on routine factory inspection work. Considerable ingenuity and expert craftsmanship are very evident as one becomes thoroughly familiar with the apparatus. The bridge is the Type 216 "Capacity Bridge" of the General Radio Company, of Cambridge, Mass., U.S.A. Fig. 1 shows a schematic circuit of the instrument. Familiarity with the construction of the bridge is of considerable importance if the operating methods which follow are properly to be understood.

Referring to Fig. 1, the ratio arms M and N have a value of 5000 ohms each. Their adjacent ends are connected by a small fixed resistance unit (indicated by ΔR), which is normally short-circuited through the connecting bar C. The flexible lead at F connects this point to the copper lining of the cabinet in which the apparatus is housed. These resistances are most carefully adjusted for accuracy and they are not incorporated in the bridge until they have been "aged"; since it has been found that wound resistances of this type may vary within appreciable limits after winding and that such "ageing" and final adjustment before incorporation are highly advisable.

Resistance *D* is a "decade resistance system" having four dials, each operating over 10 "taps." The first resistance is of a value of 10 ohms, tapped each ohm; the second of 100 ohms, tapped each 10 ohms; the third 1000 ohms, tapped each 100 ohms; the fourth 10,000 ohms, tapped each 1000 ohms. These resistances are carefully wound on the well-known Ayrton-Perry non-inductive system of winding resistances, and, in this instance again, they are carefully "aged" and meticulously adjusted to their correct resistance values prior to incorporation. This decade box occupies the forward portion of the cabinet, as

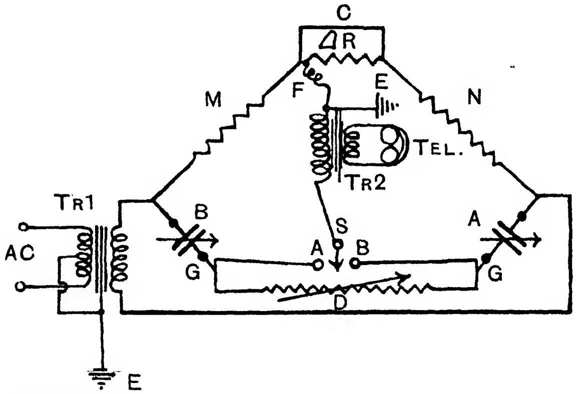


Fig. 1. Circuit of the "G.R." Type 216 Capacity Bridge described in the present article

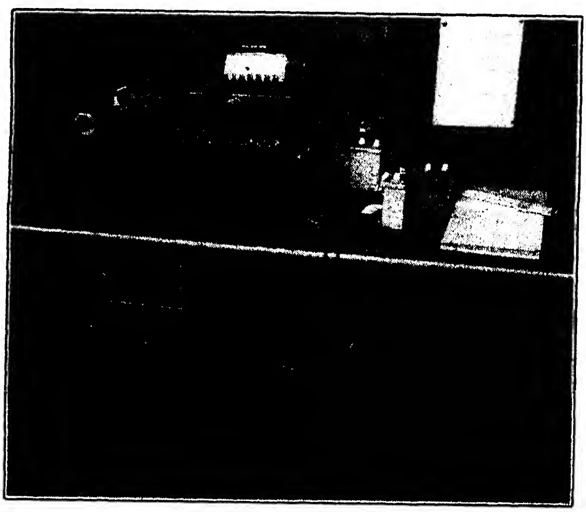


Fig. 2

may be seen from the photograph (Fig. 2). This decade resistance box may be connected in series with either arm of the bridge by the selector switch *S*, making contact at stops *A* or *B* respectively. Two condensers, *A* and *B*, constitute the third and fourth arms of this bridge.

In order to obtain the maximum sensitivity possible without the aid of an auxiliary valve amplifier (see later), both input and output transformers, *Tr* 1 and *Tr* 2 respectively, are employed. These transformers are constructed with earthed shields between their respective primary and secondary windings, to prevent errors which would otherwise be caused by capacity to earth. The mid-point of the primary of the input transformer is also earthed so that the potential impressed across each of the arms shall be equal. (The

terminals engraved "*G*" on the instrument, at arms *A* and *B* are not, however, at earth potential; they merely serve to indicate connexion to the low potential side of the condensers. In the auxiliary equipment described in this article use has been made of a "G.R." Type 246–L. "balancing condenser," of which one terminal is engraved "*G*": as the "standard condenser," use has been made of a "G.R." Type 222 Precision Condenser; and, in the case of this instrument, the low potential terminal is that one which is mounted direct on to the metal panel of same.)

As already stated, there is a small fixed resistance unit (ΔR), normally short-circuited by *C*. This is one of three standard resistance units, two further such resistances being located on pairs of terminals situated on the ebonite strip upon which the arms *M* and *N* are wound. These small resistance standards are of the order of 5, 50 and 500 ohms respectively, and their use will be explained later when reference is made to the calibration of vernier condensers. They are unbalancing resistances, providing unbalance of 0·1, 1, or 10 per cent. respectively.

Necessary Equipment and Arrangement of Apparatus

It is essential that the bridge be used in a perfectly quiet room, and it should be operated on a specially prepared table, metal-topped, this top being connected by as direct a route as is possible to an efficient "earth." There is a nickel-plated terminal on the bridge, shown near the terminals *AC*. This terminal connects to the copper lining and other shielding of the instrument, and this, also, should be "earthed."

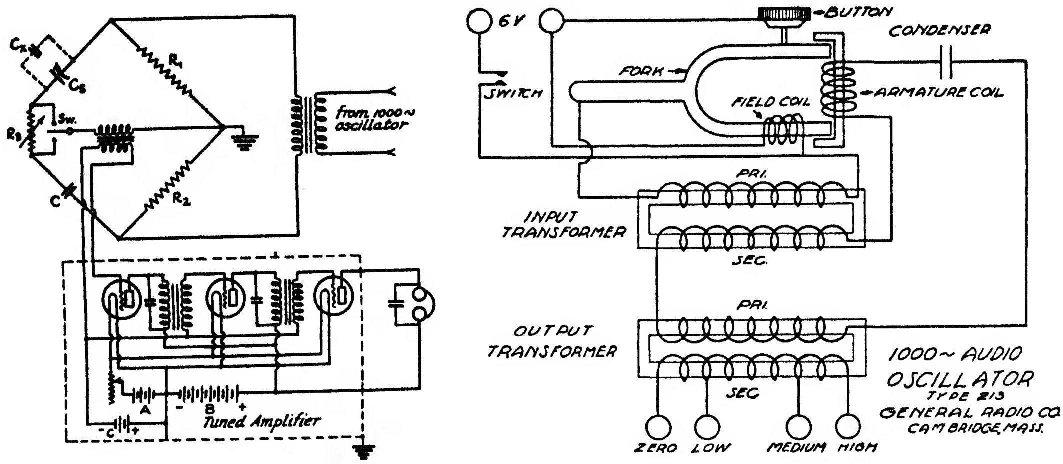
The source of sinusoidal input energy is applied through terminals *AC* to the primary of the input transformer *Tr* 1. This supply voltage may be from any source of good waveform, such as the Vreeland Oscillator; or use may be made of the "G.R." Type 213 tuning-fork controlled 1000 ~ oscillator, which is a very dependable and robust little instrument which the author has employed extensively, and which can be confidently recommended. This instrument is very cheap. It has, however, one serious drawback, that the microphone hummer within it can be heard directly through the air—quite apart from the note in the telephones—at distances of several feet, and especially in a very quiet room. On account of this it is advisable to make adequate arrangements as regards "muffling" this oscillator, or, better still, the source may be placed in another room, and connected to terminals *AC* by a pair of twisted flexes.

The precision (standard) condenser is usually most convenient when placed at the right-hand side of the bridge, *i.e.* in arm *A*, with the balancing condenser at the left, their respective high and low potential terminals connected to the corresponding terminals of *A* and *B* with heavy bare wire. The precision condenser used is of variable air-dielectric pattern, of a maximum capacity of 1500 mmF., and it has a very fine worm gear driven vernier which permits the accurate setting of the instrument to a fraction of 1 mmF.

As a "null detector" a sensitive vibration galvanometer or a pair of sensitive high-resistance telephones may be employed. One or two stages of valve amplification are desirable, but not essential, in order to reduce to a minimum the difficulties attendant on securing a perfect "null" balance. If trouble is experienced from harmonics, from the "source," or from other frequencies picked up by the wiring, a condenser and coil, tuned to 1000 ~, will usually weed out the interference, if connected across the null detector. Better still is the employment of a carefully tuned amplifier, as shown in the schematic circuit of the complete apparatus, as set up in the author's laboratory for the study of small capacities, and shown in Fig. 3.

In all the laboratory test and factory routine inspection work about to be described, it is recommended that some permanent set-up of the apparatus and leads be adopted. This can easily be accomplished by carefully thinking out a permanent wiring system, preferably

arranged on "stand-off" insulators, such as the "G.R." Type 260: such precautions greatly reduce the possibility of the introduction of errors of capacity or resistance values due to movements of load, as will be referred to later more specifically.



A B

Fig. 3 (A and B). Showing the bridge set up for the measurement of small capacities, and used in conjunction with a tuned low-frequency amplifier. The connexions of the tuning-fork controlled 1000 cycles oscillator are shown in B. (Fig. 3 A is reproduced by kind permission of "*Q.S.T.*")

General Operation

It is first necessary to have a true calibration curve of the standard condenser. The following remarks and method employed refer only to the "G.R." Type 222 Precision Condenser employed, but the method may naturally be followed with equal success in regard to any other standard condenser. The scale of this condenser is divided into 2500 equal

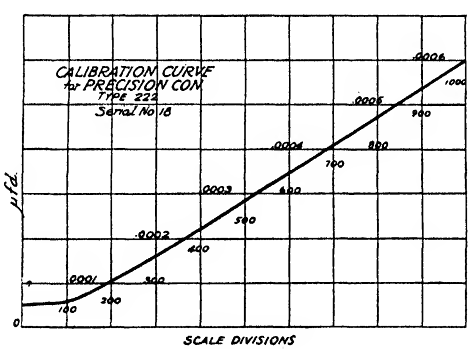


Fig. 4. Calibration curve of the "G.R." Type 222 Precision Condenser employed. From this curve the calibration tables are prepared. (See Fig. 5)

parts by the vernier gearing employed. Excepting the first 300 and the last 100, the capacity changes uniformly with each change of setting. Put differently, it is a true straight line capacity condenser between the settings 300 and 2400, and its calibration curve, for this portion of its scale, is therefore a straight line. Below 300 and above 2400 this line is not straight: this is due to "edge effects" between the stator and rotor at the moments of engagement and disengagement of the plates. The condenser is therefore employed only between the readings of 300 and 2400. On this condenser this corresponds to using the

condenser between ·00016 mF. (160 mmF.) and ·00145 mF. (1450 mmF.). The maximum capacity of the instrument is 1500 mmF.

It is essential that the instrument be most accurately calibrated for capacity* at points every 100 divisions apart, commencing at 300 and ending at 2400. These values for each 100 divisions are then plotted, on a finely hatched graph sheet, as shown in Fig. 4†. From these curves the capacity, for any given setting, may be accurately determined. If the number of readings, or the regularity of usage, warrants the labour involved, a table may be constructed as shown in Fig. 5. This table is made up as follows:

Assuming the following calibrations (from graph Fig. 4):

Condenser setting	*Capacity*
400	220 mmF. (·000220 mF.)
500	282 mmF. (·000282 mF.)

Then the capacity per scale division

= 0·62 mmF.

From which 401 on the condenser

= 220·6 mmF.,

402 on the condenser = 221·2 mmF., and so on.

It will be noted that the making up of such curve tables is not as laborious as might be imagined, as the sequence is soon recognized.

The author is indebted to Mr J. Katzman, Research Engineer of the American Dubilier Condenser Corporation, New York, for this suggestion, and the chart is one of a series, this particular one covering a range of from 400 to 859 on the condenser scale of 2500 divisions. Such a series of charts is undoubtedly a great advantage when many hundreds of readings are to be made, as the use of "curve sheets" then becomes very troublesome, and also causes considerable eye-strain owing to the optical effect produced by continual peering at fine cross-hatching. Also curve sheets become much soiled and they are also more liable to errors in reading. The chart is published with the kind permission of the American Journal "*Q.S.T.*"

400–859

	0	1	2	3	4	5	6	7	8	9
40	220.0	220.6	221.2	221.8	222.4	223.1	223.7	224.3	225.0	225.6
41	226.2	226.8	227.4	228.1	228.7	229.3	229.9	230.5	231.2	231.8
42	232.4	233.0	233.6	234.3	234.9	235.5	236.1	236.7	237.4	238.0
43	238.6	239.2	239.8	240.4	241.1	241.7	242.3	242.9	243.6	244.2
44	244.8	245.4	246.0	246.7	247.3	247.9	248.5	249.1	249.8	250.4
45	251.0	251.6	252.2	252.9	253.4	254.1	254.7	255.3	256.0	256.6
46	257.2	257.8	258.4	259.1	259.7	260.3	260.9	261.5	262.2	262.8
47	263.4	264.0	264.6	265.3	265.9	266.5	267.1	267.7	268.4	269.0
48	269.6	270.2	270.8	271.4	272.1	272.7	273.3	273.9	274.6	275.2
49	275.8	276.4	277.0	277.7	278.3	278.9	279.5	280.1	280.8	281.4
50	282.0	282.6	283.2	283.9	284.4	285.1	285.7	286.3	287.0	287.6
51	288.2	288.8	289.4	290.0	290.7	291.3	291.9	292.5	293.2	293.8
52	294.4	295.0	295.6	296.3	296.9	297.5	298.1	298.7	299.3	299.9
53	300.6	301.2	301.8	302.4	303.1	303.7	304.3	304.9	305.6	306.2
54	306.8	307.4	308.0	308.7	309.3	309.9	310.5	311.1	311.8	312.4
55	313.0	313.6	314.2	314.9	315.4	316.1	316.7	317.3	318.0	318.6
56	319.2	319.8	320.4	321.0	321.7	322.3	322.9	323.5	324.2	324.8
57	325.4	326.0	326.6	327.3	327.9	328.5	329.1	329.7	330.4	331.0
58	331.6	332.2	332.8	333.5	334.1	334.7	335.3	335.9	336.6	337.2
59	337.8	338.4	339.0	339.7	340.3	340.9	341.6	342.1	342.8	343.4
60	344.0	344.6	345.2	345.9	346.4	347.1	347.7	348.3	349.0	349.6
61	350.2	350.8	351.4	352.0	352.7	353.3	353.9	354.5	355.2	355.8
62	356.4	357.0	357.6	358.3	358.9	359.5	360.1	360.7	361.4	362.0
63	362.6	363.2	363.8	364.5	365.1	365.7	366.3	366.9	367.6	368.2
64	368.8	369.4	370.0	370.7	371.3	371.9	372.6	373.1	373.8	374.4
65	375.0	375.6	376.2	376.8	377.4	378.1	378.7	379.3	380.0	380.6
66	381.2	381.8	382.4	383.0	383.7	384.3	384.9	385.5	386.2	386.8
67	387.4	388.0	388.6	389.3	389.9	390.5	391.1	391.7	392.4	393.0
68	393.6	394.2	394.8	395.5	396.1	396.7	397.3	397.9	398.6	399.2
69	399.8	400.4	401.0	401.7	402.3	402.9	403.6	404.1	404.8	405.4
70	406.0	406.6	407.2	407.9	408.4	409.1	409.7	410.3	411.0	411.6
71	412.2	412.8	413.4	414.0	414.7	415.3	415.9	416.5	417.2	417.8
72	418.4	419.0	419.6	420.3	420.9	421.5	422.1	422.7	423.4	424.0
73	424.6	425.2	425.8	426.5	427.1	427.7	428.3	428.9	429.6	430.2
74	430.8	431.4	432.0	432.7	433.3	433.9	434.6	435.1	435.8	436.4
75	437.0	437.6	438.2	438.9	439.4	440.1	440.7	441.3	442.0	442.6
76	443.2	443.8	444.4	445.0	445.7	446.3	446.9	447.5	448.2	448.8
77	449.4	450.0	450.6	451.3	451.9	452.5	453.1	453.7	454.4	455.0
78	455.6	456.2	456.8	457.5	458.1	458.7	459.3	459.9	460.6	461.2
79	461.8	462.4	463.0	463.7	464.3	464.9	465.6	466.1	466.8	467.4
80	468.0	468.6	469.2	469.9	470.4	471.1	471.7	472.3	473.0	473.6
81	474.4	475.0	475.6	476.3	476.9	477.6	478.2	478.9	479.6	480.2
82	480.8	481.4	482.0	482.7	483.3	484.0	484.6	485.3	485.9	486.6
83	487.2	487.8	488.4	489.1	489.7	490.4	491.1	491.7	492.3	492.9
84	493.6	494.2	494.9	495.6	496.2	496.8	497.4	498.1	498.7	499.3
85	500.00	500.6	501.3	501.9	502.6	503.2	503.8	504.5	505.1	505.8

NOTE: Results are in $\mu\mu$fd. for No. 18 Condenser 3/31/25 By J.K

Fig. 5. Table from which rapid readings, in mmF., of the Standard Condenser may be taken, as explained in the text

Measurement of Capacity

Two methods of measuring capacity may be employed, one for large and one for small capacities.

For large capacities, say between ·00016 and ·00145 mF., the standard variable air condenser alone is employed, and the capacity to be measured is compared directly with it.

* *I.e.* at the National Physical Laboratory.

† The normal "cross-hatching" of Figs 4 and 7 is ten times as fine.

In the case of still larger capacities, further "standards"—fixed mica-dielectric condensers, the capacity of which has been accurately determined at a reliable laboratory—are shunted across the precision. These additional standards should be handled with care and they should be housed carefully in a cool, dry location, under lock and key.

Fig. 6 shows the set-up for the determination of such large capacities. In this method, since the resistance arms are equal, the capacity Cx is equal to the capacity of the standard $C1$. When a mica standard has to be used it should be of a smaller capacity than that of the unknown condenser Cx under test, and the balance must be obtained by adjustment of the variable standard $C1$. By employment of the standard in shunt it is possible to obtain accuracy only equal to that of the mica standard. The capacity of the unknown Cx is, of course, the sum of all the capacities of the standards in parallel.

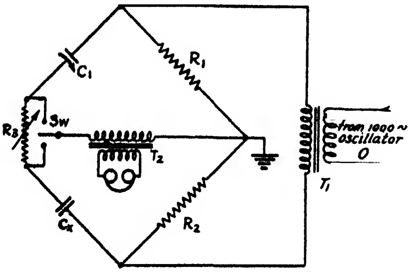


Fig. 6

By use of the substitution method capacities smaller than ·00016 can be measured accurately. This method is illustrated schematically in Fig. 3 A: in this case the complete circuit of the whole set-up, including that of the tuning-fork maintained audio-oscillator and also a tuned transformer coupled low frequency amplifier is given, instead of merely detailing the bridge circuit, which varies somewhat according to usage. In this method the standard condenser Cs is first adjusted to balance any capacity C. The value of C need not be known, *but it must not be altered.* The condenser Cx, the unknown, is connected in shunt with Cs. Cs is reduced until a true balance is again obtained. The two scale readings of the standard are then translated into terms of capacity, by reference to the capacity charts previously referred to, and the simple subtraction of one from the other gives the value of the unknown.

In both methods the decade box $R3$ should be adjusted simultaneously with the standard Cs, in order to obtain perfect balance. The closer the two are set to produce perfect balance, the more accurate are the results. The tuned valve amplifier assists considerably to this end.

Vernier Condenser Calibrations. It is frequently desirable to calibrate a vernier condenser, the total capacity of which may only be of the order of a few mmF. For this work the bridge is first balanced, using capacities of the order of 1000 mmF. If one of the resistance arms were now to be increased by one part in one thousand, *i.e.* from 5000 to 5005 ohms, the ratio of the capacities would be changed accordingly. This would be a change of 1 mmF. In order that the ratio arms may be changed in this manner, the three fixed standards of resistance, which have been mentioned previously, are employed. These units may be added to either ratio arm. Although the standard equipment of each bridge includes three of these resistances arranged so as to give ratios of unbalancing of 0·1, 1, and 10 per cent., they can be furnished to give any unbalancing ratio desired, such as ·01, ·1 and 1 per cent., or additional resistances can be supplied.

(*To be continued*)

CONTINUOUS READING OF VARYING POTENTIALS BY MEANS OF THERMIONIC VALVES. By D. T. HARRIS, M.B., Ch.B., D.Sc.

ABSTRACT. An assembly of apparatus, with steady zero reading, primarily designed for following changes in bio-electric potential differences, is described and illustrated.

The usual compensation method originated by Poggendorf for the measurement of P.D. is well suited to most physico-chemical conditions in which a stationary state of electrical equilibrium is being persistently maintained. In living organisms, however, such chemical equilibrium as exists is dynamic and is developed only with the expenditure of energy;

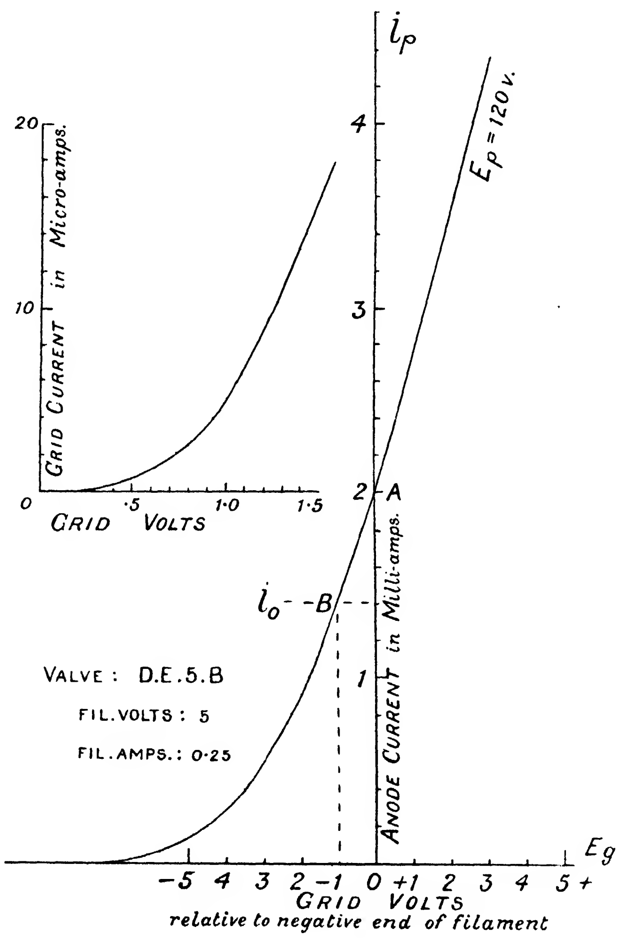


Fig. 1. Characteristic curves of a D.E.5B. (Marconi) thermionic valve

also the concomitant processes of electrolytic dissociation are in a state of continuous flux. For the study of the varying P.D.'s set up in biological work, an instrument is desirable which can follow the changing conditions without appreciable lag and without the production of such polarization effects as might be incurred in the customary compensation method during the search for the null point.

The advent of the 2-electrode valve and its further development in 3-electrode form has provided us with a means of expressing a static potential applied to the grid of a triode valve in terms of an electro-kinetic quantity, namely, the corresponding plate current, which is very easily measured and derives its energy from a secondary independent source. As difficulties of maintaining a constancy of zero have been met with by workers who have tried to measure P.D. in terms of thermionic currents, a detailed account of how to surmount these difficulties is here presented.

The relation between the two quantities is shown graphically by the so-called characteristic curve of the valve, which in the case of the D.E.5B. (Marconi), the valve recommended for this type of work, is shown in Fig. 1. For the purpose of calibrating the valve the voltage to be applied to the grid may be suitably led off from a 2-volt accumulator in conjunction with a potentiometer outfit (the portable model of the Cambridge Instrument Company is very convenient for this purpose), and the plate current read off on a milliammeter as in Fig. 2.

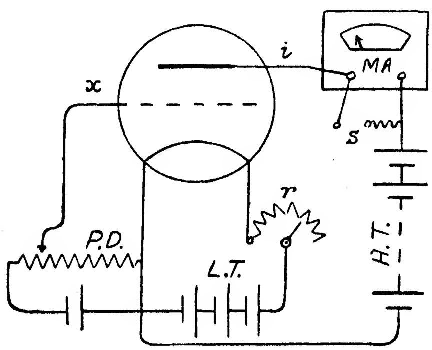


Fig. 2. Calibration of the valve for grid bias ranging 0 to -2 volts. i = plate current; x = grid voltage led from *P.D.*; *P.D.* = potential divider; r = series filament resistance; *M.A.* = milliampere meter; *S.* = shunt; *H.T.* = high tension battery; *L.T.* = low tension battery

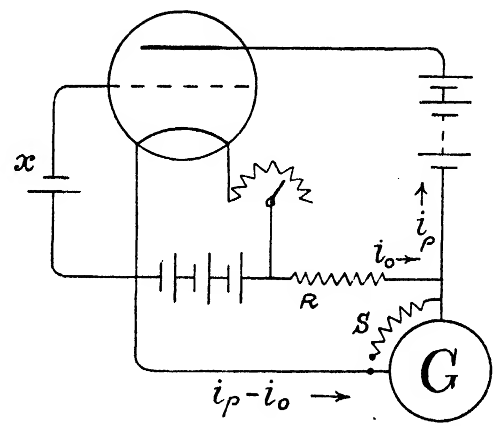


Fig. 3. Compensation of the initial thermionic current by an opposing galvanic current i_0 taken from the filament-heating battery

If now an unknown voltage x be applied to the grid and the accompanying plate current is read off, its value may be ascertained from Fig. 1, or if the grid voltages are not below -1 an approximately linear relationship holds between these two variables.

In order to read the plate current with a greater degree of accuracy, the milliammeter may be replaced by a more sensitive galvanometer, provided the main part of the plate current be compensated by an opposing current through the instrument. The latter may be taken from the filament battery, as shown in Fig. 3, in the method originally employed by Goode for his continuous reading electro-titration apparatus*. This increased sensitivity of the recording instrument, however, serves only to magnify the falling off of the E.M.F. of the batteries. This may be brought to a practicable minimum by employing batteries of larger capacity and lower voltages in conjunction with a 4-electrode dull emitter valve (Figs. 4 and 5) or confining the use of the circuit of Fig. 3 to experiments of short duration. But in all these methods difficulties arise from the falling off in the discharge rate of the batteries with time, and these may be most conveniently surmounted by compensating the thermionic current passing through the galvanometer by a second similarly varying thermionic current rather than a galvanic one. The additional initial outlay in duplicating valve,

* *Journ. Amer. Chem. Soc.* 44 (1922) 26.

filament and high tension batteries is fully repaid by the constancy of zero obtained by opposing the standing plate current of the first valve by means of a second identical set. The drift in the zero is then usually less than the equivalent of a rate of change of grid potential of 1 millivolt per hour; this may further be reduced in proportion to the care taken of the accumulators. Fig. 6 shows the diagram of a circuit which is easy to handle and quickly calibrated.

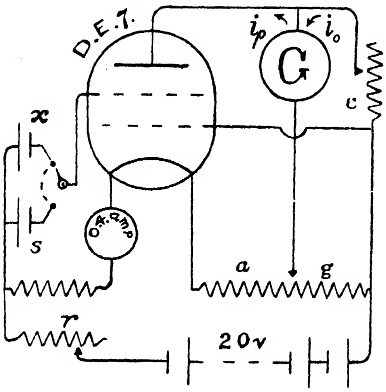


Fig. 4. Four-electrode valve (Marconi D.E. 7) working from a single battery which supplies filament current, grid voltages, and compensating current. x = unknown P.D.; s = standard cell

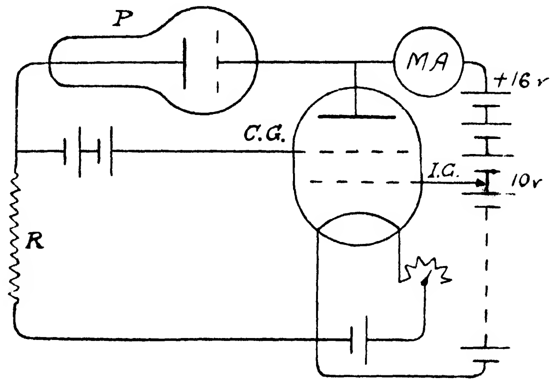


Fig. 5. Adaptation of Fig. 4 for use with a photo-electric cell P. (The leak R must start either from the + ve or − ve of the biassing battery. The best arrangement and grid biases can be found by trial)

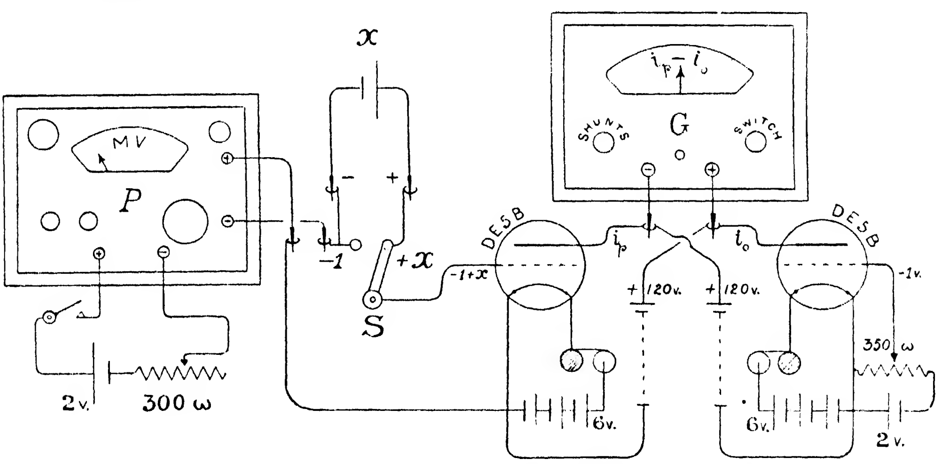


Fig. 6. The 2-valve potential indicator* $x = k\,(i_p - i_o)$

The two high-magnification valves, of nearly identical characteristics, are mounted in an anti-vibration duplex valve-holder (Marconi) and derive their energy each from its own filament battery (40 ampere hour capacity) and high-tension battery (5 ampere hour capacity, *e.g.* exide type W.H.).

With the rapid commercial development of wireless telegraphic and telephonic appliances, new or improved components have appeared which are finding useful application in physical methods of measurement, and one of interest in the present connection is the so-called "straight line" filament resistance which is continuously adjustable—not in steps, as is

* Made by Baird and Tatlock (London) Ltd., 14, Cross Street, Hatton Garden, E.C. 1.

usual,—and consists (Fig. 7) of a eureka wire (w) being wound on a vulcanite cylinder whilst unwound from a metal cylinder, with an ingenious mechanical device for keeping the wire taut; there is no contact arm with questionable electrical contact. This renders the equalization of the opposing plate currents an easy and exact operation.

The measuring instrument may either be a laboratory galvanometer (reading to 10^{-8} amp.) provided with ample shunts, or more conveniently a multirange microammeter, *e.g.* a mains test set (Cambridge Scientific Instrument Co.) shown at G in Fig. 6.

We have now to decide upon the amount of negative grid bias to be applied to each of the valves in the initial compensated condition. A glance at the characteristic curve (Fig. 1) will show that this is almost linear for a limited distance on either side of the vertical axis corresponding to a grid potential of zero volts, and, if a nearly proportional relationship between the grid voltage and plate current

$$E_g \propto i_p - i_o$$

is desired, we must confine ourselves to the straight portion of the curve. Further, we are still limited to the left side of the vertical axis, since the grid potential must never rise above that of the negative end of the filament, otherwise electrons will be drawn into the grid and, passing through the grid circuit, cause polarization in any cell included in it; the magnitude of such a grid current for various voltages applied to the grid is shown in the smaller curve in Fig. 1. It must be observed that with some types of valves, grid current may start as far back as $-0{\cdot}5$ volts. It is necessary with D.E.5B. valves, therefore, to work in the region AB between 0 and -1 volts on the grid, if polarization of the cell in the grid circuit is to be avoided.

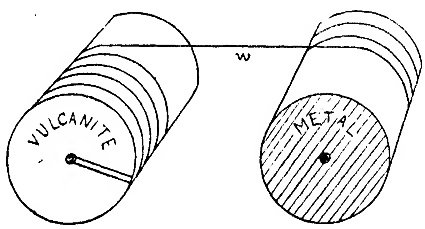


Fig. 7. "Straight line" filament rheostat

No current could be detected for this range of grid bias, in the assembly shown in Fig. 6, when a mirror galvanometer reading to 10^{-9} amps was placed in the grid circuit. Similar considerations show that a soft valve is unsuited to this work because ionization of residual gas may give rise to a flow of positively charged ions into the negatively biased grid. Grid current also introduces the further complication that the valve no longer possesses infinite resistance and thus one is subject to the usual errors which occur with low resistance voltmeters.

The first step in the adjustment, therefore, is to fix the simple grid potential divider on the right-hand valve which is supplied by a 2-volt accumulator to tap off $-1{\cdot}0$ volt, and a similar bias on the left-hand valve with the 2-way switch S on -1 by means of the correct setting on the portable potentiometer P (Fig. 6). Next switch on the accumulators for the left-hand valve, and with the galvanometer shunt set for reading in milliamps, adjust the filament resistance so that the plate current is somewhat short of saturation (about $1\frac{1}{2}$ milliamps); let this value be i_o. Now switch in the right-hand valve and increase its filament current until it yields the same value i_o, thus wiping out the galvanometer deflection; remove the galvanometer shunts in turn, perfecting the adjustment at each stage.

The initial zero conditions thus correspond to a negative grid bias of 1 volt. If the latter

magnitude is diminished by a quantity x volts then the plate current of the left-hand valve will be increased to a new value i_p while the galvanometer will show the reading $i_p - i_o$. The cell

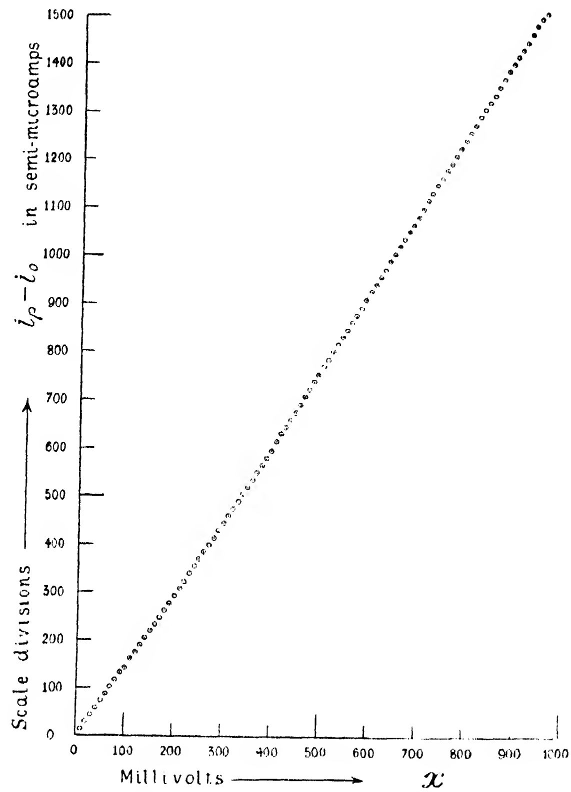


Fig. 8. Calibration of a 2-valve potential indicator: Scale divisions × 0·65 = millivolts

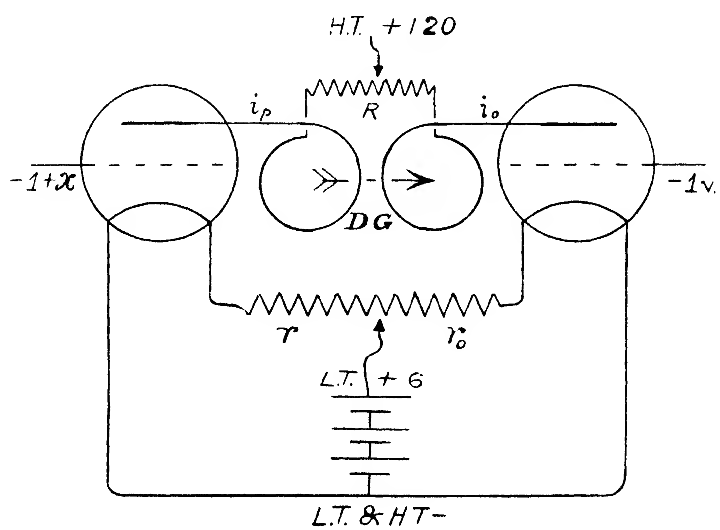


Fig. 9. Method of compensation, using two valves with only one set of accumulators

whose P.D. "x" is to be measured is inserted in the grid circuit in opposition to the grid bias by moving the switch arms on to $+x$ (Fig. 6). It will be readily seen and easily verified that over short ranges the relation $x \propto i_p - i_o$ connecting the desired P.D. with the galvano-

meter reading is a simple one (Fig. 8), *e.g.* with one pair of valves a change of 1 millivolt on the grid caused a deflection of 1·5 divisions on the microammeter or 3/4 microamps per M.V. (1 scale division = 2 microamps in this instrument).

Among the many uses to which this 2-valve potential indicator may be applied may be mentioned the following:

1. The measurement of electrode potentials in the manner outlined in Fig. 6.

2. The maintenance of constant P.D.'s, as in fluids to be kept at a constant pH, by utilizing the current $i_p - i_o$ to operate a relay in conjunction with a suitable amplifier (2 valves).

3. In some cases to replace the quadrant electrometer, since P.D.'s associated with fairly large resistance may be incorporated in the position of x (Fig. 1). It is not, however, recommended for enormous resistances such as are encountered in a glass electrode.

4. Photo-electric potentials (or more simply but less accurately as in Fig. 5).

The arrangement enables one to follow the variations in electrode potentials under the action of light, examples of which will be described in a subsequent paper dealing with photo-electrolytic responses.

If the cost of the installation of duplicating batteries is a serious one the arrangement (Fig. 9) suggested by Mr C. S. Agate, to whom I am indebted for much helpful advice, may be used. The two valves are compensated by a potentiometric type of battery resistance $r + r_0$, and the plate currents are led off through a differential galvanometer D.G. and balancing resistance R.

THE INFLUENCE OF VARIOUS GASES UPON WIRE VIBRATION IN A CORONA DISCHARGE TUBE. By

J. E. SNYDER AND G. M. EVANS. Department of Chemistry, The Pennsylvania State College.

[*MS. received*, 10*th March*, 1928.]

ABSTRACT. In an all-glass corona discharge tube of the wire-coaxial cylinder type, a wire which is still during a 60-cycle discharge in air, ammonia, oxygen, hydrogen or hydrogen-nitrogen mixtures vibrates when these gases are replaced by nitrogen, carbon monoxide or methane. Vibration was prevented by sealing the wire while it was electrically heated and under tension.

In corona discharge tubes of the wire and coaxial cylinder type, the vibration of the wire under the influence of an alternating current discharge is well known. This is prevented by having the wire carefully centred and under tension. The latter is usually effected by the use of some contrivance such as a spring or a weight attached to one end of the wire. Under these circumstances, only one end of the wire can be permanently sealed to the base of the cylinder, which therefore necessitates the use of rubber tubing, sealing wax, a mercury seal or other means to seal the free end of the wire to the cylinder.

In attempting to construct an all-glass discharge tube in which very pure nitrogen was to be used, it was found that the wire, although perfectly still in air, vibrated to such an extent in nitrogen that the tube could not be used. The corona tube consisted of a platinum wire coaxial with the inner tube of a Pyrex Liebig condenser and sealed through the glass at both ends. The wire served as the high potential electrode, and dilute hydrochloric acid, which was circulated through the condenser jacket by means of an air lift, served as the grounded electrode and as a cooling medium.

Attempts to centre the wire more carefully and increase the tension did not eliminate the vibration. Decreasing the length of the wire was also ineffective. The wire, apparently centred and perfectly still in air, vibrated in nitrogen. Experiments were made to show the effect of other gases, using a tube 1·2 cm. in internal diameter and 37·3 cm. in length. The condenser jacket was 30·3 cm. in length. The platinum wire, extending the full length of the tube was 0·51 mm. in diameter (B. & S. gauge 24). The gases listed in Table I were passed successively through the discharge tube, a 60-cycle discharge being maintained at 13,700 volts. The results are given in Table I.

Table I. *Gases producing vibration*

Number	Gas	Discharge current milliamp.	Vibration
1	Air	3·3	None
2	Nitrogen	2·5	Vibrates
3	Oxygen	3·2	None
4	Nitrogen	2·7	Vibrates
5	Oxygen	3·3	None
6	Nitrogen	2·7	Vibrates
7	Hydrogen	3·2	None
8	Nitrogen	2·7	Vibrates
9	Hydrogen	3·2	None
10	Nitrogen	2·7	Vibrates
11	Air	3·5	None

The wire was also found to vibrate in methane or carbon monoxide in a similar tube.

A discharge tube 65 cm. in length has been used in the study of the synthesis and decomposition of ammonia. No wire vibration occurred either when the tube was filled with pure ammonia or a 3 to 1 ratio by volume of nitrogen and hydrogen. The gases in these experiments were not circulated.

A tension upon the wire sufficient to prevent its vibration in nitrogen was finally effected by electrically heating the wire and sealing it while hot and under tension. Additional tension due to contraction results upon cooling. This treatment was only partially successful. The wire remained still only as long as the nitrogen was still, or moving at slow velocities. At higher gas-velocities, vibration set in.

It is quite possible that under different operating conditions or with another design of tube, the vibration effect may be eliminated entirely or reversed in the various gases. When vibration does occur, however, it is evident that the gas surrounding the wire has a considerable influence.

NEW INSTRUMENTS

LABORATORY CURVE TRACER

One of the most striking developments of experimental technique in the past few years has been the increasing use of instruments for graphically recording the deflection of mirror instruments over short periods of time. When the deflection varies so rapidly that it is impossible to take separate observations a recorder is essential, but additional advantages of the recording instrument lie in the greatly enhanced accuracy which is obtained and in the saving of time effected in obtaining the results of the particular experiment in hand. A deflection may be varying irregularly over a distance of, say, 2 millimetres, so that by single observations it would be difficult to fix the exact deflection, but if the variations are recorded on a chart the mean position may be accurately determined. In addition, the use of a simple graphically recording instrument, rather than a photographic camera, saves time

and labour and does not entail the same manipulative skill. Also, in many instances the record is required over such a short period of time that it is hardly worth the trouble of setting up a camera and developing a negative.

The instrument illustrated, the design of which is based on the curve tracer for recalescence work developed by Mr Harry Brearley, is made by the Cambridge Instrument Company, Ltd., 45, Grosvenor Place, London, S.W. 1. It will record any mirror deflections, and will, so to speak, replace the observer and his note-book by a record showing at a glance the complete course of the experiment. It consists of a drum *A* (Fig. 1) carrying a chart (36 cm. long by 30 cm. wide) and mounted with its axis parallel to an ordinary divided scale *B*. The drum may either be rotated by clockwork or set free and made to rotate in synchronism with any other feature of the experiment. Above the chart is mounted a pen *C* which may be traversed the length of the drum by a leading screw operated by the handle *D*. Attached rigidly to the pen is a fine cross wire *E* which moves parallel and close to the scale *B*. A beam of light from the moving mirror is focussed on to the scale, and, as it moves up or down the scale, the observer brings the cross wire continually into coincidence with the image and thus

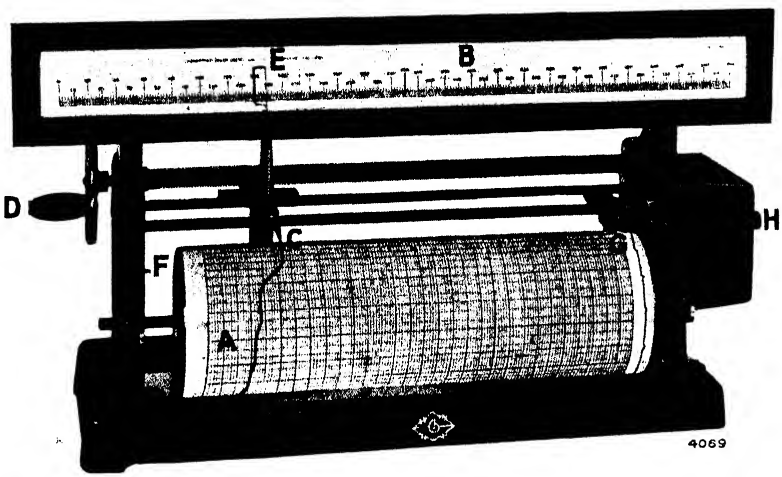


Fig. 1. Laboratory Curve Tracer

causes the pen to trace a corresponding record on the chart. To obtain a clear record it is essential that the cross wire be brought into coincidence with the spot of light before recording is commenced, and this is achieved by lifting the handle *F*, thus raising the pen just clear of the paper, and yet keeping the pen-holder engaged in the screw. As soon as the observer has picked up the spot of light, recording is commenced by lowering the handle *F*. When the spot of light moves suddenly to another part of the scale, as, for example, if the deflection is reversed by some key, the pen-holder may be rapidly traversed by disengaging it from the leading screw by hand, and sliding it along the bar.

A fixed pen *G* mounted at one end of the drum is used for marking on the chart the exact instant at which certain events occur, such as when the connexions are reversed, etc. or for making some conventional sign to indicate the stage of the experiment. The drum may be rotated by clockwork to make one revolution in either 10 minutes or 30 minutes, the change over being carried out in a few seconds by sliding a gear wheel along the main axle. A lever *H* also allows the drum to be stopped or started at will, or the drum may be rotated so that any desired portion comes under the pen. Further, one end of the shaft has been left free to enable any other driving mechanism to be fitted.

Typical records obtained with the apparatus are reproduced in Figs. 2 to 5. The first

three curves (Figs. 2 to 4) show different types of cooling curves obtained by means of a thermocouple and a mirror galvanometer. Fig. 2 is the cooling curve for lead, and shows a normal rate of cooling until freezing commenced, when the temperature remained stationary for a considerable time until freezing was completed, when the normal logarithmic curve was continued. Fig. 3 shows the cooling curve for paraffin wax. A normal logarithmic cooling curve was obtained until the wax began to solidify. As, however, it has no definite

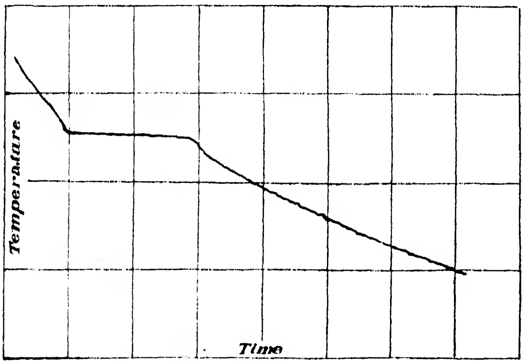


Fig. 2. Cooling curve for lead

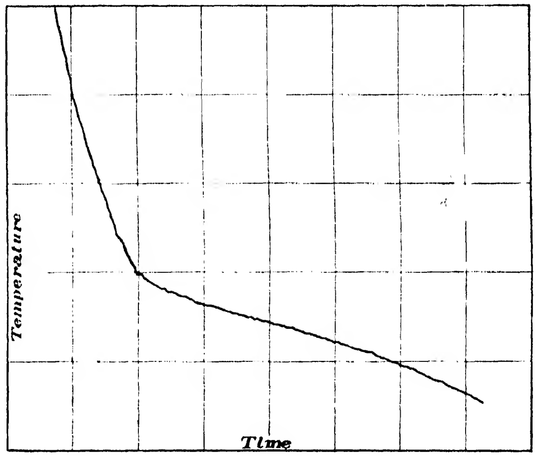


Fig. 3. Cooling curve for paraffin wax

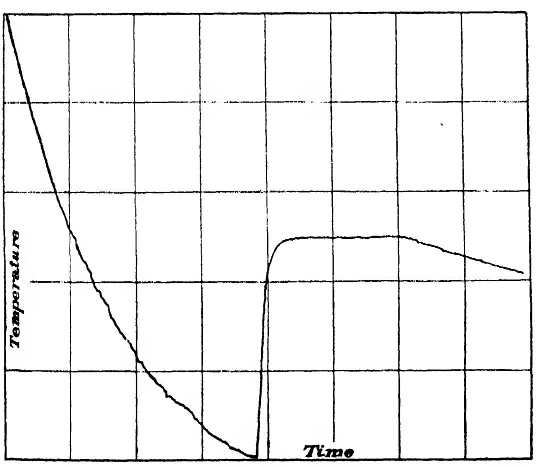


Fig. 4. Evolution of heat from a super-cooled solution of sodium-thiosulphate

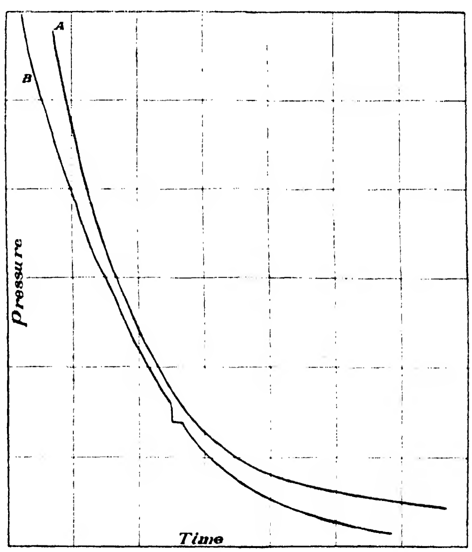


Fig. 5

freezing point, the rate of cooling was then merely reduced until freezing was completed, when the rate of cooling again quickened and followed the normal logarithmic curve. Fig. 4 shows the rate of cooling of a solution of sodium-thiosulphate. This curve commenced with a normal logarithmic cooling curve and the solution became super-cooled below the normal crystallization temperature until crystallization suddenly started. Crystallization then proceeded rapidly and the solution heated up to the normal crystallization temperature. The temperature then remained constant until crystallization was complete, when cooling again proceeded, following the usual logarithmic curve.

The records reproduced in Fig. 5 were obtained by filling a closed cylinder with air at slightly above atmospheric pressure, and then allowing the air to escape slowly, first through a long capillary tube (curve *A*) and then through a small hole in a thin plate (curve *B*). To the cylinder was connected a pressure gauge, the glass front of which was removed and a small mirror was fixed on to the top of the indicating needle. The pressure gauge was laid on its back and was then used with a lamp and the curve tracer in the usual way.

In the first experiment the velocity is proportional to the pressure, that is to the excess pressure in the closed vessel above that of the atmosphere. Curve *A* should therefore be a normal logarithmic curve. Careful measurement of the curve produced shows that this was the case, at any rate up to quite low values of the pressure, when instrumental errors due to the pressure gauge used became important.

In the second experiment the flow is governed by Bernoulli's equation $p + \frac{1}{2}\rho V^2 =$ constant, that is, the flow is proportional to the square root of the pressure. The record traced should, therefore, be a parabola, and this is verified by careful measurement of curve *B*. The hump in this curve was due to some sudden vibration relieving part of the friction on the pressure gauge with the result that the pressure fell suddenly. It then remained constant until the pressure came back to the normal curve. The fact that the whole curve is plotted enables such sources of error to be eliminated, whereas had an observer with a watch and note-book taken a reading on such a hump the curve plotted by him would probably have been steeper at this portion than that obtained by taking the true mean value of the pressure.

The curve tracer is of rigid design and at the same time sufficiently portable to be easily carried from place to place. When once an observer has formed the habit of recording his observations on a chart, instead of writing them in a note-book, instruments of this type should have a wide range of applications.

THE DEVELOPMENT OF THE HOT CATHODE X-RAY TUBE

FROM the once familiar glass bulb, the trend of modern hot cathode tube design seems, at the moment, to lie in an entirely different direction. This is largely due to the activities of Messrs Philips Lamps Limited, 145, Charing Cross Road, London, W.C. 2, who have devoted a good deal of attention to this problem; the excellent glass-to-metal seal developed by this Company playing an important part in the construction of the X-ray tubes which bear their name.

Most laboratory workers are familiar with the difficulties in connexion with joining metal to glass, and, briefly, the Philips method consists in the use of an alloy formed of approximately 75 per cent. iron and 25 per cent. chromium. This has an average temperature coefficient of about 10×10^{-6} per ° C., a figure which practically corresponds to that of glass. It also possesses a low heat conductivity and can be heated to 1000° C. without detriment. In making a glass-to-metal junction, using chromium iron, the edge of the metal is usually bevelled off, and is afterwards "wetted" by means of a thin glass ribbon which is melted on. The glass portion is then brought into position and the blowpipe allowed to play on both components simultaneously.

Joints made on this principle are perfectly vacuum tight, and possess remarkable mechanical strength. It is interesting to consider that Dr Bouwers*, using a corrugated cylinder of chromium iron to which glass insulating cylinders were directly sealed, was able to vary the distance between two electrodes to the extent of several millimetres. This was accomplished by applying mechanical pressure to the vacuum tube, from the outside.

* Philips Laboratory, Eindhoven.

Fig. 1 shows the external appearance of a Philips "Metalix" X-ray Tube. The method of construction can be gathered from the sectional drawing, Fig. 2. To a chromium iron cylinder is sealed two glass insulating arms. By the use of a re-entrant tube at each end, the electrodes are thus supported within a metal enclosure. A jacket of lead of adequate thickness placed round the chromium iron forms a rational solution of the protection problem,

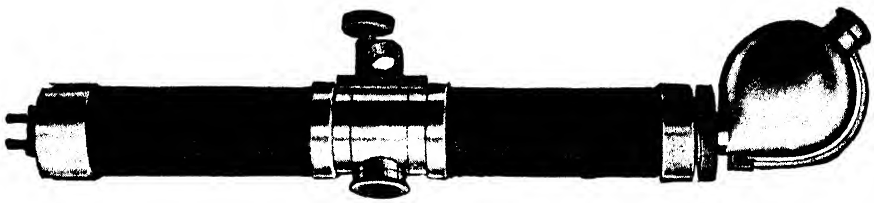


Fig. 1

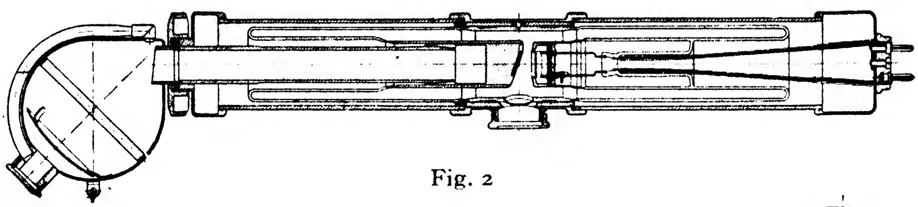


Fig. 2

Fig. 3

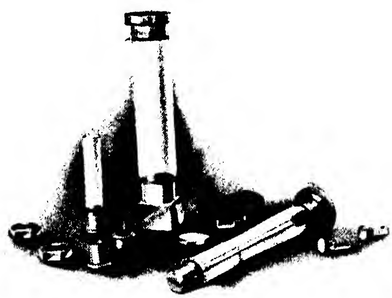


Fig. 4

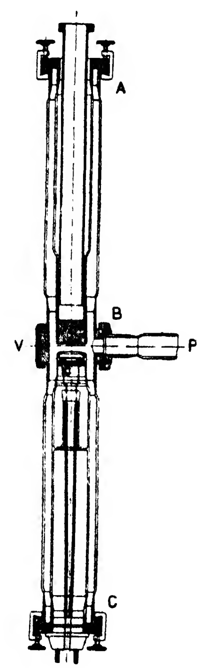


Fig. 5

whilst a small soda glass window permits the passage of the X-ray beam. A screwed ring at the aperture permits the insertion of various filters. For visual examinations, in a darkened room, this is a useful feature. Complete darkness is assured, as the light from the incandescent filament is completely screened by a jacket of bakelite, which also affords mechanical protection to glass portions of the tube. The total weight of the "Metalix" being only 6 lb. it is not surprising to find it in very extensive use among the medical profession. It would also appear to offer many advantages to the laboratory worker.

Under working conditions, the potential is distributed evenly along the length of the tube, so that the central metal portion is practically at zero potential. This permits the close proximity of a spectrograph or other apparatus.

"Metalix" tubes of a similar pattern are also available for operation at voltages up to 220 kV.

For pump operation, demountable tubes of a very convenient form have recently been marketed. The chromium iron alloy referred to above is again very freely used in the construction. From Fig. 3 the general arrangement can be seen quite clearly. The design is such that no wax or cement is required in making the joints vacuum tight. All removable components are provided with machined chromium iron faces, which when clamped with a rubber washer between them, ensure sound vacuum tight joints. The pump connection is secured to the body of the tube by means of a screwed union joint.

A similar method is adopted in connection with the mounting of the anti-cathode. This, together with the easy way in which the cathode can be withdrawn, makes the tube one which is remarkably convenient to handle. Fig. 4 shows the tube dismantled. This type of tube can be worked up to potentials of 55 kV (peak) and from 10 to 20 mA continuously, depending upon the efficiency of the water cooling arrangements. The anti-cathode end of the tube can, of course, be earthed if the transformer permits of this being done with safety. For voltages up to 130 kV (peak) these demountable tubes are available in a larger size. The general form can be seen from Fig. 5, which shows the tube in section.

LABORATORY AND WORKSHOP NOTE

A RELAY FOR ALTERNATING CURRENT.

By FRANK ADCOCK, M.B.E., B.Sc.

An electrical relay of the usual "bell magnet" type, while cheap and suitable for use with direct current, cannot be readily employed in alternating current circuits, owing to the violent chattering of the armature which takes place in sympathy with the periodicity of the exciting current. Since alternating current is now available in many dwelling houses, an inexpensive relay capable of working on this form of electrical supply would find a ready application in burglar alarm and similar circuits.

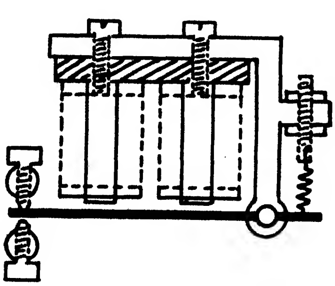


Fig. 1

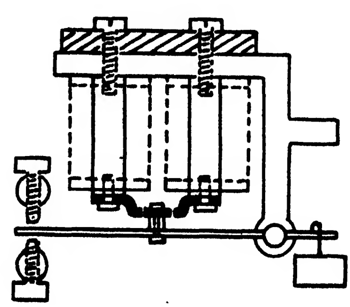


Fig. 2

The writer has successfully modified a relay of the ordinary direct current type so as to permit of its use with alternating current, and it is thought that the method may be of some general interest. Such a modified relay is suitable for circuits where the relay contacts are open, so long as the magnet coils are excited and are closed when for any reason the exciting current is interrupted.

Fig. 1 shows diagrammatically the unaltered relay, and Fig. 2 the relay as modified for use with alternating current. In making the change it is necessary to replace the usual iron armature by a piece of brass of similar shape on which is mounted a narrow strip of iron as indicated in Fig. 2. When the exciting current is passed through the magnet coils the relatively small armature is drawn between the specially shaped extension pole pieces which are attached to the magnet cores. Since the magnetic force merely tends to hold the iron armature in the gap between the extension pole-pieces the moving part of the relay is "floating" and is not in contact with any stop against which chattering might take place. With a supply current of 50 cycles per sec. frequency the vibration of the movement can be just felt by hand but no appreciable sound is emitted. Although the tractive force acting on the armature is quite sufficient to operate the relay when the customary tension spring is replaced by a small balancing weight, it is much less than that present in the unmodified relay, a result partly attributable to the different position of the magnet yoke in the modified relay.

In the particular type of relay experimented upon it was necessary to change the position of the yoke (shown hatched in figures) in order to gain the extra space needed for the extension pole-pieces and the special armature. A relay designed specially for alternating current work would of course be provided with a better magnetic circuit than is easily obtained in any improvised arrangement, and this in turn would result in an improved performance.

REVIEWS

Physics in Medical Radiology. By SIDNEY RUSS, D.Sc., F.Inst.P., L. H. CLARK, Ph.D., F.Inst.P., and B. D. H. WATTERS, M.Sc., A.Inst.P. London: Chapman and Hall, Ltd. Pp. xii + 234. Price 12*s*. 6*d*. net.

The ever-increasing use of physical methods of diagnosis and treatment, which has been one of the features of modern medical practice, has undoubtedly created serious problems for the medical practitioner. For the compounding and administration of drugs very modest knowledge of chemistry sufficed; such knowledge as was in fact included in the ordinary medical course. Physical agents—X-rays, ultra-violet rays, high frequency currents and the like—are by no means so readily handled without technical training. They must be produced, on the spot, by elaborate and fragile machinery, and their accurate measurement involves delicate apparatus of a not too familiar type. The very brief course in the elements of physics included in the preparation for the first medical examination affords very little basis for the understanding of the highly specialized branches of physics which are now employed in medicine.

It is true that manufacturers of electro-medical appliances have done marvels in the way of smoothing the path for unaccustomed feet. Modern sets of apparatus can be purchased which will produce X-rays, of sorts, with very little more skill and knowledge than is involved in pressing a button. Medical radiologists and electro-therapeutists have, however, been the foremost to recognize the inadequacy and the danger of rule of thumb methods in the application of such powerful agents. That some knowledge of the physics both of the agents themselves and of the means of production is essential to the equipment of a properly qualified radiologist is amply recognized by the universities, which now grant diplomas in the subject.

The volume under review has been written primarily to meet the needs of medical men who are studying for one or other of these diplomas, and it is from that standpoint that it must be considered. In normal circumstances a pure physicist might well look askance at a text book which commences with the calculation of the capacity of a parallel plate condenser, and of the resistance of conductors in series and in parallel, and, in the course of a couple of hundred pages, is dealing with alternating current circuits, high tension generators and high frequency currents, having taken the physics of X-rays and radioactivity in its stride. It goes without saying that the student, however closely he studies such a text, will not find himself at the end either an electro-technician,

a radio-chemist, or an X-ray physicist. To admit this, however, is not to detract in any way from the merits of the present volume. A work of this kind may fail more easily from attempting too much than too little. What is required is that the information, so far as it goes, shall be up-to-date and scientifically accurate; that the material selected shall be that which it is most useful for the reader to know; and that it shall be expounded in such a way as to convey to him a clear and distinct idea of the general principles underlying the whole.

These are requirements of no small order. Possibly only those who have actually had to face the problem personally will realize all the difficulties it presents. Professor Russ and his assistants at the Middlesex Hospital, however, start with two initial advantages. They are in close touch with radiological work on an extensive scale, and they have had several years' experience of actual teaching of the classes for which the book is written. It may be said without hesitation that they have done their work well. The material is admirably chosen for its purpose, and the medical radiologist will find in this volume an appreciable part of what he needs to know of the physics and technology of the subject. While aiming necessarily at simplicity of statement, the authors have not allowed themselves to be led into inaccuracy or looseness either of thoughts or expression, and there are very few statements or definitions at which the strictest scientist could cavil. The exposition throughout is lucid, and numerous diagrams and illustrations illuminate the text. Numerous numerical calculations are employed to illustrate the significance of those mathematical expressions which are so essential to the subject, and yet so meaningless to the medical man to whom they so often constitute an unknown tongue.

The book is, in fact, so well adapted to its purpose that it is almost impossible to suggest any improvement. Occasionally, while reading, the thought would arise whether a reader who really required the elementary physics of the first chapters would be capable of keeping up with the authors in the very hot pace which they set; whether in condensing a three months' course of instruction into little more than two hundred pages some explanations or amplifications had not been squeezed out which might profitably have been retained. If so, no doubt the present high cost of book publication is responsible.

The publishers, as well as the authors, have done their work well. The book is admirably printed and produced and the price is reasonable. We can confidently recommend this volume to all practitioners of medical radiology; to those who are facing the trials of a diploma examination it is indispensable.

J. A. C.

A Text Book of Experimental Psychology. Part II. Laboratory Exercises. By CHARLES S. MYERS, M.A., M.D., Sc.D., F.R.S., Director of the National Institute of Industrial Psychology; and F. C. BARTLETT, M.A., Director of the University Psychological Laboratory, Cambridge. 3rd edition, Cambridge University Press, pp. 131. Price 7*s*. net.

Experimental psychology, though the youngest of the experimental sciences, and until lately hardly taken seriously by orthodox scientists, is beginning to be recognized as an important study having useful practical applications; and if "the proper study of mankind is Man" it is well that this should be so, as it is of no less importance that we should ascertain his psychological as his physiological characteristics and needs. In the present small volume, Dr Myers and Mr Bartlett have given us an excellent and clear introduction to the methods and instruments used in experimental psychological study, and the fact that it has already reached its third edition is sufficient evidence of its utility.

The volume is essentially of an introductory character, and is mainly devoted to the study of the five special senses, and of muscular fatigue. This part of the subject, though of less interest and importance than the more modern investigations of fundamental aspirations and repressions, forms a solid basis for training the budding experimental psychologist, and is of interest to readers of this *Journal*, as many of the investigations involve the use of apparatus. The various instruments employed in such investigations are clearly described, but to the experimenter familiar with physical apparatus they give the impression in most cases of crudity and lack of absolute character. We have already reached the point where acoustic, thermal, and luminous radiation can be expressed and measured in terms of energy; and there should be even less difficulty in devising instruments for the expression of touch, taste, and smell in definite units. One cannot help being struck with the

great field which experimental psychology offers for the introduction of new instruments, but even at the present time there are certain instruments which might advantageously be taken into psychometric service, *e.g.* the phonic chronometer, the audiometer, the Maxwell and other colour boxes, and the various instruments for measuring thermal radiation. We should also have expected to find some space devoted to the study of electrical stimuli and nerve impulses, which lend themselves excellently to laboratory study.

In comparison with other subjects one gets the impression that the ground covered by this book is small for a two years' course of study, and that more might have been made of the practical applications of the science, especially as Dr Myers is so intimately associated with one aspect at least of its sociological relationship. The study of the specific senses is at best but a part, and the more mechanical part, of psychology, and while economics, industry and hygiene are progressing rapidly towards satisfying our bodily needs, the chief aim of psychology, even from the outset, should be to discover the means to bring contentment and harmony to our minds. In view of the already assured popularity of this book, it is to be hoped that another edition will soon be called for, and that its scope will be enlarged.

C. V. D.

NOTICES

INTERNATIONAL CONGRESS FOR TESTING MATERIALS

It is announced that the *Proceedings of the International Congress for Testing Materials*, Amsterdam, 1927, will shortly be issued. The book will consist of two volumes of about 650 pages each, royal octavo. Before the War the International Association for Testing Materials held well-attended Congresses every three years, but these were discontinued, owing to the War, after 1912. The Congress at Amsterdam in 1927 marks the resumption of the activities of the Association.

The *Proceedings* contain the full text of the papers presented at the Congress, and include the following, which were read at the General Meetings: T. D. Lynch (East Pittsburgh), Material Testing as a Stimulus to Research; A. Mesnager (Paris), Rupture des Solides; Prof. Dr phil. F. Körber (Düsseldorf), Das Problem der Streckgrenze; W. Rosenhain, F.R.S. (Teddington), The Plastic Deformation and Fracture of Metals. The papers presented at the Section Meetings include contributions from all parts of the world. Section I, Metals, comprises Special Steels, Metallography, Abrasion Testing, Hardness Testing, Impact Tests, Endurance Tests, etc. Section II, Cement, Concrete, Stone and Bricks, comprises Reinforced Concrete, Cement Testing, Refractory Materials, etc. Section III, Miscellaneous, includes Oils, Caoutchouc, Preservatives against Corrosion, Wood and Coal.

The publishers of the *Proceedings* are Messrs Martinus Nijhoff, The Hague, and the price of the two volumes is 30 Guilders (£2. 10*s*. 0*d*.).

EXHIBITIONS IN CONNEXION WITH THE SEVENTH INTERNATIONAL CONGRESS OF PHOTOGRAPHY

An important feature of the forthcoming International Congress of Photography is to be the holding of a series of exhibitions in connexion with each of the sections of the Congress. These will be international in character, and will be open free to everybody and not confined to members of the Congress. The exhibition of pictorial photography will consist of a number of prints by British and foreign workers specially invited by the Pictorial Committee of the Congress. In the other sections a certain number of exhibits will be invited, but the Hon. Secretary will be pleased to hear from anybody who would desire to exhibit matter

showing recent advances in photographic practice, scientific-photographic apparatus, illustrations of recent advances in the knowledge of the theoretical aspects of photography, new photographic apparatus, and so on. There will be a special section devoted to trade exhibits in all branches of photography and its applications. Members of the photographic trade who may be desirous of exhibiting new material are asked to communicate with the Hon. Secretary as soon as possible. The amount of space available for the exhibition is limited.

As far as is known at present, no charge will be made for trade space in the exhibitions, but it may be necessary to make a small charge for insertions in the Exhibition Catalogue, in order to cover the cost of the catalogue.

The Royal Photographic Society's house at 35 Russell Square will be used for the Pictorial Exhibition only. The others will be held at the Imperial College of Science and Technology, South Kensington, S.W. 7, which is the meeting place for the Congress.

The address of the Hon. Secretary is Dr W. Clark, The Science Museum, South Kensington, S.W. 7.

INTERNATIONAL ILLUMINATION CONGRESS

Particulars have been received of the International Illumination Congress, to be held in September at Saranac Inn, N.Y., on all the important branches of lighting in which investigation is going forward. Among the subjects to be discussed are: lighting for aviation, street and highway lighting, store and window lighting, factory, library, hospital and public building illumination and floodlighting.

Not only will the laboratory and commercial practice in these subjects be reviewed and plans made for further work, but the foreign delegation will also see much of American illumination practice while in the United States. The tour, which is being planned to take in a number of American cities in the eastern half of the United States, will provide for inspection of important installations of all kinds. Niagara Falls and Toronto will be included in the itinerary.

Preparations are being made for the Congress under the auspices of the Illuminating Engineering Society, 29 West 39th Street, New York, N.Y., and of the U.S. National Committee of the International Commission on Illumination.

JOURNAL OF SCIENTIFIC INSTRUMENTS. BACK NUMBERS

Two shillings per part will be paid for clean, undamaged copies of parts 1, 2, 4, 11 and 12 of Volume 1 of the *Journal*. These should be sent to the Secretary, Institute of Physics, 1 Lowther Gardens, Exhibition Road, London, S.W. 7

LABORATORY AND WORKSHOP NOTES

Readers of the *Journal* are reminded that notes concerning laboratory or test-room methods, and workshop devices or methods of utility to instrument-makers are welcomed, and that ten shillings will be paid for each such note published.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V JUNE, 1928 No. 6

TEMPERATURE MEASUREMENTS IN RESEARCH ON AIR-COOLED INTERNAL COMBUSTION ENGINES.

By J. F. ALCOCK, B.A.

[*MS. received*, 14*th April*, 1928.]

ABSTRACT. Thermocouples used on air-cooled cylinders of petrol engines are apt to be very inaccurate, owing to the cooling effect on the leads of the high speed air blast used to cool the cylinder. Measurements were therefore made of the errors occurring with various couples in common use, also with a type of couple specially designed to reduce the error to a minimum.

THE thermometry problem described in these notes, though rare, is yet of some general interest since in it arise, in exaggerated form, difficulties which to some extent occur in many other applications.

In the operation of an air-cooled engine the temperatures at various parts of the cylinder are factors of vital importance, since on them depend the efficiency of the engine and, even more, its mechanical reliability. A theoretical estimate is hardly practicable, owing to the complexity of the factors involved, and some method of measurement is therefore essential. The conditions to be met are somewhat peculiar. The average aero engine cylinder consists of a symmetrical finned steel barrel, of wall thickness only about $\frac{1}{8}$ in., with an irregular shaped head, carrying valves, etc., of thicker section in aluminium alloy. Owing to these thin sections, the thermocouple forms the only practicable means of thermometry.

A very high rate of heat dissipation is essential, and this is provided by a cooling blast averaging 100–130 m.p.h. It is this powerful blast that makes it so difficult to obtain accurate temperature readings. To it the thermocouple leads are necessarily exposed, and they act as adventitious cooling fins, abstracting heat from the hot junction, which in turn obtains it from the cylinder metal. This heat flow causes local chilling of the cylinder metal, particularly in thin sections; while if there is imperfect thermal contact between the hot junction and the adjacent metal, the junction will be cooler than the metal. Good thermal contact is, as a matter of fact, not easy to obtain, since soldering, brazing, etc., are impracticable in most cases.

For these reasons the couples tend to give low readings, and the high cooling rate tends to make these errors serious. In one case which the writer actually met with the error exceeded 30 per cent. To get accurate readings, therefore, the junction must be in good thermal contact with the cylinder metal, and must lose little heat along the leads. Further, these leads must be so thin as not to appreciably obstruct the flow of cooling air; otherwise local overheating may occur. The standard of accuracy required is not very high, consistent errors of say 3 per cent. and variations of $\pm$ 1 per cent. being unimportant. Ordinary commercial direct-reading galvanometers are therefore quite suitable.

Thermocouples for engine work fall into two classes:

(*a*) "Fixed" couples, permanently affixed in one position. Generally the wires, or small plugs brazed thereto, are wedged or screwed into small holes in the cylinder walls. Fig. 1 shows a typical construction. These are used in inaccessible positions or where frequent readings are required.

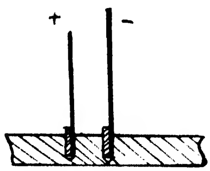


Fig. 1. Wedge Type Buried Couple

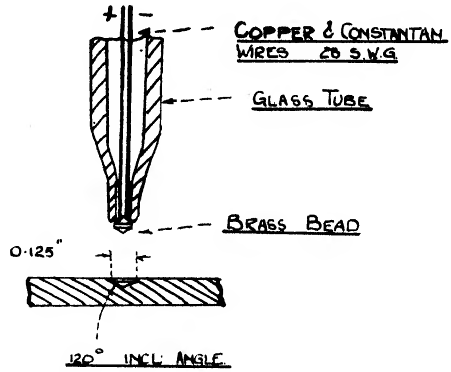


Fig. 2. Bead Type Contact Couple

(*b*) "Contact" couples, which are held in the hand, and pressed into a shallow hole in the cylinder wall when a reading is required. These are convenient for the large number of positions where occasional readings are required, as in such cases the use of buried couples would involve a maze of wiring. A common form, shown in Fig. 2, consists of a small brass bead, carrying the junction and mounted on the end of a glass tube, up the bore of which pass the leads. The tip of the bead is roughly conical, and is, in use, pressed into a shallow hole, formed by a 120° angle drill, in the cylinder wall.

With both these types the trouble lies in poor thermal contact between the wire and the cylinder. The buried type is, as a rule, the better of the two, but is not easy to fit in thin metal. Moreover, a wedged in wire is only in local contact with the hole, and a well fitting screw is difficult to make in small sizes. The same trouble applies even more forcibly to the bead type, which is rarely a good fit in its hole. It is clear that, with the more or less casual fits that are unavoidable in these small sizes, there must be, in many cases, a bad contact, or "thermal bottle-neck," across which there is considerable temperature drop. In the constructions hitherto described the thermojunctions are on the cold side of this bottle-neck, hence the errors.

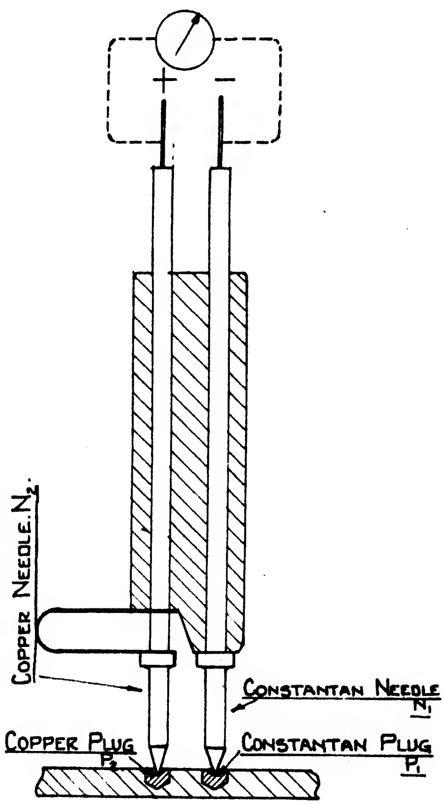


Fig. 3. Plug-and-needle Thermocouple

The writer therefore sought for a means of locating the junction proper, that is, the point of contact of dissimilar metals, on the hot side of the bottle-neck. The method evolved is applicable to couples both of the buried and the contact types. As applied to the latter it is shown diagrammatically in Fig. 3. Into holes in the cylinder wall

are tightly driven small plugs P_1, P_2 of copper and constantan (or other thermoelectric pair), which plugs are then countersunk as shown. On these plugs are then pressed, when a reading is desired, needles N_1, N_2 of the same materials, and to these needles the indicator leads are connected.

With this arrangement the true thermojunction is on the outside of the plugs, where the two metals meet that of the cylinder wall, and this, being for all intents and purposes part of the wall, is practically at the wall temperature. The needle-to-plug contacts are not thermojunctions, since the metals are similar, and serve only to conduct the current. They are, therefore, deliberately made bad thermal contacts, so as not to chill the plug, while their electrical resistances are not serious since the total circuit resistance is, as a rule, fairly high.

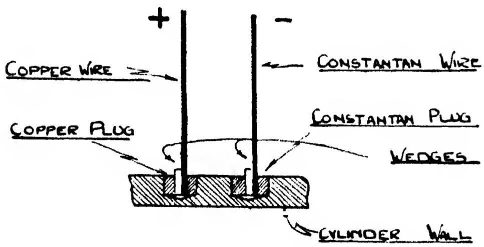


Fig. 4. Buried Thermocouple Plug-and-wire Type

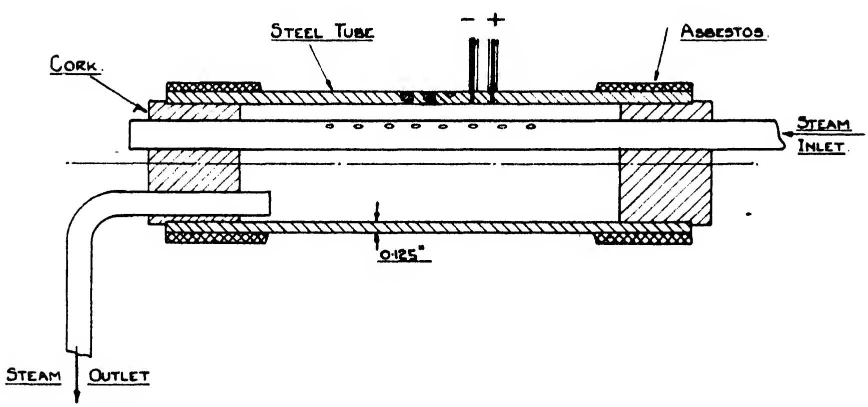


Fig. 5. Apparatus for Testing Contact Pyrometers

The fixed form of this couple is shown in Fig. 4. Here the plug is hollow, and a thin wire lead is wedged therein. The wedge may be of any material provided that the wire and wedge do not touch outside the plug, but in practice this is difficult to ensure, and it is desirable, therefore, to make the wedge of the same metal as the wire and plug.

Having evolved this type of couple, the writer set to work to test it. To this end was employed the apparatus shown in Figs. 5 and 6. This consisted of a mild steel tube 1·5 in. outside diameter and wall thickness 0·125 in. In its walls were arranged, as shown:

(*a*) Copper and constantan wires, 20 S.W.G., soft soldered into holes in the cylinder wall, to form a buried couple. To reduce heat loss along the wires these were lagged with asbestos thread.

(*b*) A shallow drilled hole, $\frac{1}{8}$ in. diameter, for use with a contact couple of the type shown in Fig. 2. The hole was drilled with a standard 120° drill, which was stated to be correct for the particular couple employed. This couple was not made by the writer's firm, but was one used elsewhere in research on air-cooled engines. It consists of copper and

constantan wires of 28 S.W.G., with their ends brazed into a small brass bead about $\frac{1}{16}$ in. diameter, roughly shaped to a 120° point. The wires were carried inside a pencil-shaped lead-glass tube which served as a holder. This couple will hereafter be called the "bead" couple.

(*c*) Two plugs, one of copper and one of constantan, for use with the plug-and-needle system of Fig. 3. These plugs were 0·128 in. diameter, made from 10 S.W.G. wire, and driven into flat-bottomed holes 0·125 in. diameter and 0·1 in. deep. They were then filed flush with the tube and countersunk. The two plugs were in line axially and about $\frac{3}{16}$ in. apart. The needles for use with these plugs were made of 10 S.W.G. wire, with points ground roughly conical with an included angle of about 30°. The extreme tips were rounded off, though with no attempt to fit the countersinks in the plugs. This couple will hereafter be termed the "needle" couple.

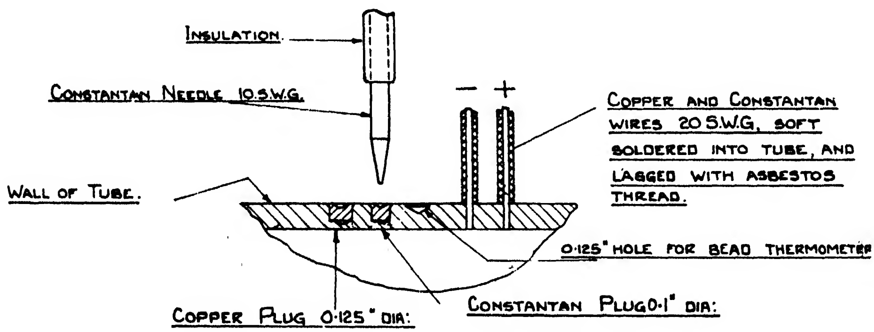


Fig. 6. Section of Wall and Plugs

The tube was heated internally by steam at atmospheric pressure, supplied through a perforated pipe, the perforations being so arranged as to give a rapid steam flow, and therefore an effective heat transfer, in the region of the thermocouple.

ELECTRICAL APPARATUS

The galvanometer used was a Cambridge Instrument Company's portable indicator of 395 ohms resistance, giving direct temperature readings with copper-constantan couples. The cold junction was immersed in an oil (xylol) bath, to the temperature of which was set the zero of the instrument.

CALIBRATION

Calibrations were made, at 100° C., individually for each couple, this being necessary owing to the fact that different batches of wire were employed for the different couples, so that the instrument readings were not in all cases directly applicable.

The bead and needle couples were calibrated in steam, in the latter case by joining the two needle tips with copper wire. The buried couple was calibrated *in situ*, by passing steam through the tube, the outside being heavily lagged with cotton wool to reduce heat loss. The figure so obtained agreed with that found for a second couple made of the same batches of wire and tested in steam.

To imitate the conditions obtaining with an actual cylinder the tube was mounted in the outlet duct of a fan, with the couples on top so as to receive a tangential blast. Wind speeds up to 125 m.p.h. were available, and were measured, about half-an-inch off the tube surface, by a special small pitot tube and indicator calibrated by the National Physical Laboratory. Some slight error may have been caused by the proximity of the tube, but the exact speeds are of no great importance.

Tests

These were carried out in still air (except for convection currents) and in winds of 82 and 105 m.p.h. The bead couple was tested in holes in steel, copper and constantan, so as to observe the effect on the accuracy of the couple of the thermal conductivity of the metal. All the holes were carefully cleaned before use, and the bead "ground" into the hole while taking the reading.

To obtain the errors of the various couples it was necessary to know the temperature of the outer surface of the tube, which would be lower than that of the steam, owing to the heat drop across the metal and across the steam-metal inside surface. To obtain this the rate of heat loss was measured by "cooling meter"*, and the heat drop across the metal obtained from this and known conductivity. The figures so obtained were of course only approximate, but as the total drop was only about 2° C., no reasonable errors would be of any practical significance. The drop, if any, at the steam surface was ignored, and the true outside temperatures should thus be lower than those given, but the difference was probably very small.

The figures obtained are given after correction for differences in calibration, etc. in the following table:

Table I.

Wind speed, m.p.h.	—	0	82	105
Surface temperature, calculated °C.	—	100	98·6	98·2
Buried couple	Reading	100	94·0	93·0
(Soldered wires)	Error %	0	4·6	5·2
Bead couple in steel hole	Reading	86	70·5	68·0
(Th. condy 0·12)	Error %	14	28·1	30·2
In copper hole	Reading	88	77·0	71·0
(Th. condy 0·91)	Error %	12	21·6	27·2
In constantan hole	Reading	82	67·0	61·0
(Th. condy 0·06)	Error %	18	31·6	37·2
Needle couple	Reading	100	97·0	97·0
	Error %	0	1·6	1·2
(Check test with second pair of plugs)	Reading	100	97·5	97·0
	Error %	0	1·1	1·2
(Needles in steel holes)	Reading	90	85·0	87·0
	Error %	10	13·6	11·2

From these figures we can draw the following conclusions:

(1) The soldered couple, in spite of good thermal contact, gives errors of about 5 per cent., due presumably to local chilling of the wall by the wires.

(2) With the bead couple the errors are truly appalling, averaging about 30 per cent. They depend not only on the wind speed but also on the thermal conductivity of the metal. Apart from the absolute error, it seems unlikely that this type of couple would give even relative accuracy, since the error depends on the rate of cooling, which is different, for example, in the front and rear of a cylinder, and these differences are not always known. Thus, a correction factor could hardly be used. This type of couple may be consistent in the sense that, in a given position and under given conditions, the error will be constant, but that is all one can say for it.

The needle type, on the other hand, gives remarkably small errors under all conditions. It may be that even these are fictitious, and due merely to temperature drop at the steam surface, which would cause the true wall temperatures to be lower than the calculated ones, and thus produce an apparent error. The readings were quite unaffected by reasonable variations in the pressure on the needle points, or by tilting the needles, etc. Burring over

* A special type of Katathermometer. Vide *The Automobile Engineer*, April 1927.

the needle points and smothering the plugs in oil and dirt had likewise not the least effect. The system therefore appears to be eminently a practical one under ordinary test conditions.

The test with the needle in the steel holes shows that the plugs are a vital part of the system, in steel at any rate, and cannot safely be omitted for the sake of simplicity. They are also of interest as showing that only about 12 per cent. of the temperature drop takes place in the plug. Thus, any slight alteration in the thermoelectric properties of the latter, due to the cold work it undergoes during the process of fitting, will have no appreciable effect on the total E.M.F.

Contact Resistance

It was thought possible that the electrical resistance between the needles and plugs, though negligible in the high-resistance circuit used in the above tests, might be serious with an instrument of low resistance, such as is generally desirable. Measurements were therefore made of the contact resistance with various loadings on the needle. These showed that even with a loading of only 20 gr. the contact resistance was 0·025 ohm, a value utterly negligible in practice, while blunting the needle points made no serious alteration. Thus, the question of contact resistance can be ignored in practice.

Permanent Couples

In a later series of tests the writer set himself the task of evolving a permanently fixed couple, the use of a contact type being in some cases impracticable. The steam heated tube described above was therefore again brought into service, being fitted with fresh couples of the types under investigation.

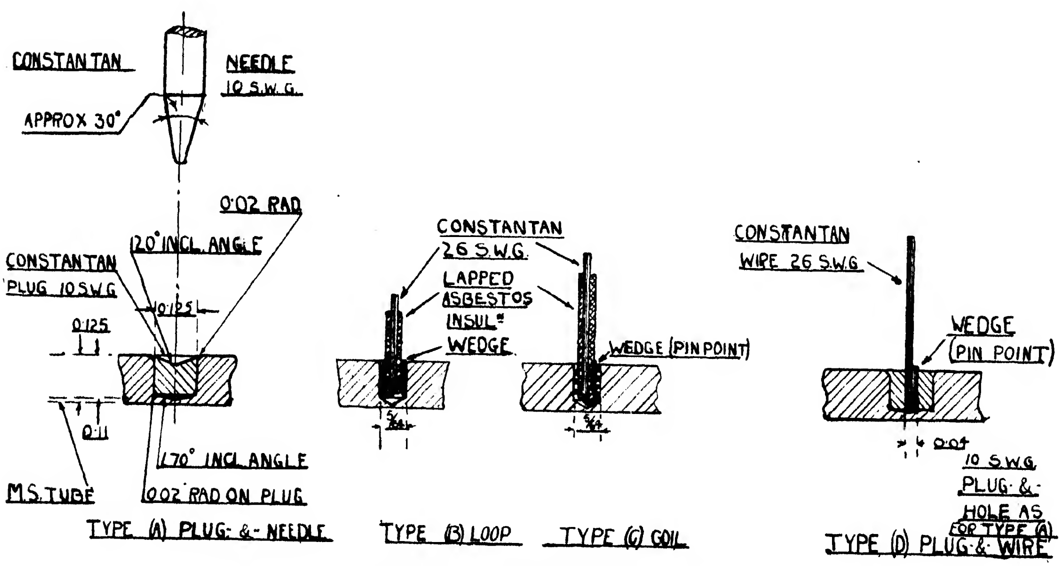


Fig. 7. Types of Couple Tested

The couples used in this case were all nichrome-constantan instead of the former copper-constantan, a change made on the advice of the National Physical Laboratory. Nichrome has for this work many advantages over copper, more particularly its greater mechanical strength, which reduces the risk of breakage, and its low heat conductivity, which reduces cooling errors.

Four types of couple were tested, and are shown in Fig. 7.

(*a*) A plug-and-needle contact couple, tested for purposes of comparison. This is of exactly the same type as in the earlier tests, except for the use of nichrome instead of copper.

(*b*) *Loop Type*. In this each lead (26 g. single asbestos lapped) runs to the bottom of its hole in the metal, and a bared portion is turned back, the whole being then wedged into position with wedges made from common pins. The object of this construction is to reduce error due to heat flow along the wire, by increasing the distance from the point of contact of the wire with the wall to the point where it meets the air blast.

(*c*) *Coil Type*. This type is similar to (*b*), but the bared wire is coiled around the down lead so as to present a greater surface in contact with the side of the hole. The coil is expanded by a pin wedge into tight contact with the wall of the hole. This type of couple proved very difficult to make. A second couple of this type was also tested in order to detect variations due to errors in fitting.

(*d*) *Plug-and-wire Type*. In general terms this has been described above. The test plugs were of 0·125 in. diameter and 0·1 in. depth, as for type (*a*), and the lead 26 g. bare wire. The wedges were driven in flush and were made from common pins. In practice, however, the writer finds it preferable to use slightly projecting wedges, which can be withdrawn if the wire breaks off short, thus leaving the hole clear. Such wedges are conveniently made by filing up 20 g. constantan or nichrome wire.

Tests

The couples were mounted as before, so as to receive a tangential blast, tests being made in still air and in winds of 68 and 115 m.p.h. Calibration was effected *in situ*, the tube being lagged with cotton wool. The readings given are corrected for the calibration so found. The instrument was a Foster direct-reading indicator, with 60 ohms total circuit resistance. The figures obtained are given in the following table:

Table II.

Wind speed, m.p.h.		0	68	115
Estd. surface temp. °C.		100	98·7	98·0
Contact couple (*a*)	Reading	100	97·8	96·8
	Error %	0	0·9	1·2
Loop couple (*b*)	Reading	100	90·0	85·5
	Error %	0	8·7	12·5
Coil couple (*c*)	Reading	100	97·5	96·2
	Error %	0	1·2	1·8
(Check, second couple)	Reading	100	95·7	94·5
	Error %	0	3·0	3·5
Plug-and-wire couple (*d*)	Reading	100	98·0	96·0
	Error %	0	0·7	2·0

As before, the plug-and-needle type (*a*) gives small errors, while the plug-and-wire (*d*) is practically as good. The coil type (*c*) is fairly accurate, but is very difficult to fit, while type (*d*) is easily fitted and more accurate. The loop couple (type *b*) is hopelessly inaccurate.

Conclusion

These tests show that careful design of couples is needed to prevent serious error. The two types mentioned, however, give sufficiently accurate results, and are fairly easy to make and fit. The plug sizes quoted are perhaps too large for very thin cylinder walls, but there is no objection to the use of smaller ones (except difficulty in fitting), though in the writer's case it happened to be unnecessary.

The writer would like to thank Messrs Ricardo and Co. at whose works the tests were done, and the Air Ministry, on whose behalf they were made, for permission to publish these notes. He also thanks the Thermometry Section of the National Physical Laboratory for much useful advice on the selection and treatment of apparatus and material.

THE PHOTOMETER BENCH. By JOHN F. SUTTON, M.Sc. (Eng.).

[*MS. received*, 17*th February*, 1928.]

ABSTRACT. The author reviews the various types of photometer bench on the market and criticises them from the point of view of accurate experimental work, pointing out the lack of features which are essential when making measurements with any degree of precision.

The various essential adjustments and readings in obtaining a photometric comparison are enumerated and are followed by a list of the methods available for carrying out the adjustments. A design is then given of a photometer bench which incorporates all the above features and which has been found to be suitable for the accurate comparison of all kinds of lamps.

ANYONE who has endeavoured to carry out accurate measurements on the types of photometer bench on the market will realize that hardly any are supplied with all the necessary fittings; and that many improvements are possible in details of construction.

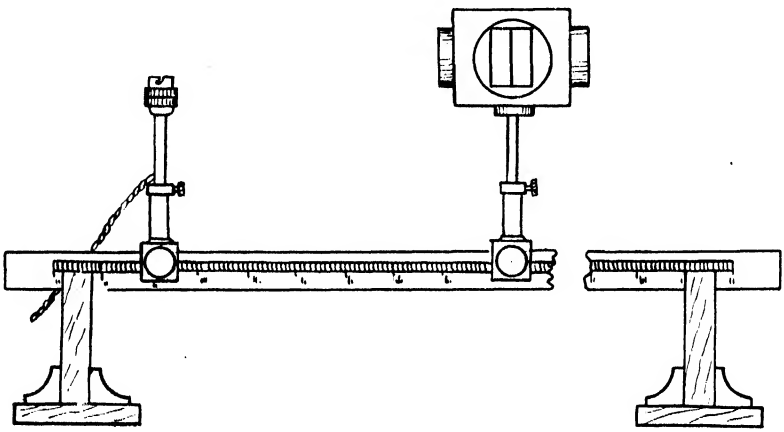


Fig. 1. Primitive Photometer Bench

The author has been unable to find in any catalogue a description of a bench which does not need some kind of auxiliary apparatus to avoid the possibility of introducing serious errors. An example of a primitive type of bench is illustrated in Fig. 1. While such a bench might be quite suitable for demonstrating the principles of photometric measurements in a school, it is quite hopeless for use in the laboratory. The standards for the lamps and photometer are much too flimsy and there is no means of showing if they are vertically above the pointer. The trolley for carrying the photometer itself is of very poor design and has no pretensions to rigidity. Moreover, as the scale is fitted into the front of the bench it is not illuminated by the lamps themselves and an auxiliary light is needed for taking readings.

A more elaborate type of bench is shown in Fig. 2. Instead of having only one guide, two steel rods or tubes are provided, with the scale engraved on the top of the front one. As the rods are generally oxidized to a dark colour it makes the scale very difficult to read. The trolleys have three wheels, shaped like cotton reels, to keep them in position. This feature is a considerable improvement over the former type of bench, as the trolleys are at least rigid. A mistake is generally made however in using three flanged wheels instead of two flanged wheels on the front guide and one flat one on the back. Any irregularity in

the guides will cause a much greater lateral displacement in the former case than in the latter. The guides themselves are not stiff enough to remain straight of their own accord and must be mounted on a heavy bench and levelled up by means of adjusting screws on the supports.

In addition to this no means are provided for adjusting the pointer on each trolley to be in the same plane at right angles to the line of the bench as the filaments of the lamps themselves. The only measurements one has to record on the bench itself are the various distances between axis of lamp and photometer head. It is therefore obvious that one should be able to adjust a pointer to be in the same vertical plane as the lamp or instrument above it, so that the distances between pointers represent the true distances between the lamps or between lamp and photometer.

The greatest physical difficulty and source of error in carrying out photometric measurements lies in the inability of the eye to compare two surfaces of nearly the same brightness, and it has been stated by a well known writer that the greatest accuracy possible in comparison is of the order of one part in 500. In order to take advantage of this it is clearly essential that any other errors which are introduced shall be of a much smaller magnitude

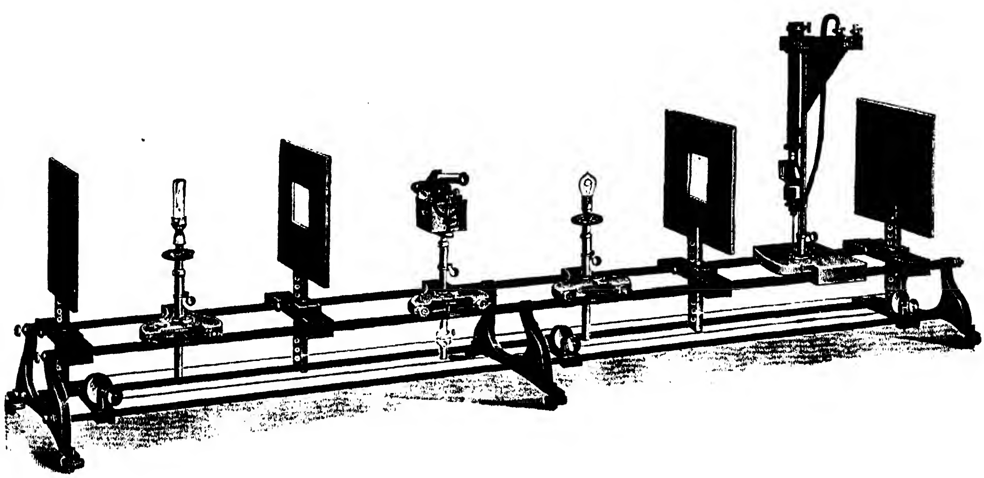


Fig. 2. Improved Bench

than this. For example, it should be possible, with suitable apparatus, to ascertain readily the distance between a photometer head and a lamp two metres away without introducing an error of more than one millimetre; which in terms of brightness represents an error of one part in 1000.

One might enumerate the essential features of a photometer bench as follows:

(1) The bench should be straight and rigid on its own base without requiring additional support except at each end. This feature is also the chief characteristic of a lathe bed and makers would do well to follow the designs which have been found by experience to be the most suitable for the latter purpose.

(2) The trolleys carrying the lamps and photometer head should run freely along the bench without "shake" or vibration.

(3) They should carry pointers which are adjustable in the direction of the bed.

(4) A device should be incorporated in the apparatus by means of which it is possible to adjust each pointer so that it is in the same plane, perpendicular to the length of the bed, as the lamp filament or photometer disk.

(5) The scale should be placed in such a position that it is illuminated by the test lamps themselves.

(6) The lamp holders and the photometer should be capable of rough vertical adjustment and should be quite rigid on their respective trolleys.

(7) Arrangements should be made for fitting light screens without interfering with the motion of the trolleys.

(8) A device should be fitted so that, if brightness comparisons are made with the photometer head stationary, one or other of the lamps may be moved by means of a wheel close to the head.

Fig. 3. Specially Designed Bench

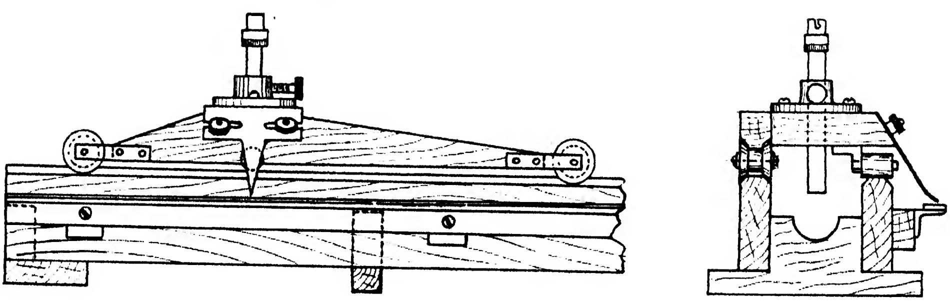


Fig. 4. One of the trolleys

Fig. 3 shows a design which has been carried out as far as possible in accordance with these requirements. The bench is 12 feet long, and the two bearers are made of teak 5 in. × $1\frac{1}{4}$ in. in section, fitted with five spacing pieces. Cross bracing is introduced at the centre portion of its length to improve the lateral stability.

Although the bench made in this way is sufficiently rigid if supported only at each end on a trestle, for the sake of convenience it has been mounted on a bench 14 feet long which provides accommodation for a Pentane standard lamp at one end. Fig. 4 shows a drawing of one of the trolleys. The trolleys each have three bearings: the two rear wheels are made in the form of cotton reels to act as guides and the front one is a plain roller. The pointer is adjustable in the direction of the length of the bench, and to set it in the same vertical

plane as the lamp, the steel framework seen in Fig. 3 is provided, having a plumb line front and back. These plumb lines are also very convenient for the purpose of setting the Pentane standard at a known distance from the end of the scale. The lamp holders are screwed to ⅜ in. diameter steel conduit, which is made a sliding fit in a brass tube having a flange fastened to the base of the trolley.

It was not considered necessary to mount the photometer head on a trolley with wheels, since most measurements are carried out with the head stationary. A simple rigid fitting was designed which could be moved along the bench. Two guides are provided, one sliding along the inside of the back bearer and the other along the top of the front bearer. These two serve to prevent the head from turning or tilting. The head is interchangeable with a lamp holder so that if necessary it can be mounted on a trolley. Similar means for setting the pointer in the same vertical plane as the photometer disk are provided as for the trolleys themselves.

It may be of interest to describe here the method which has been adopted for calibrating a substandard electric lamp against the Pentane standard. The Pentane standard is set up at the right-hand end of the bench, and adjusted for position relative to the axis of the bench. The photometer head is placed at 150 cm. from the standard, its pointer having been previously adjusted, and on the left-hand side is a trolley containing a carbon filament lamp of about 8 candle power. The light from this lamp is adjusted to be as near as possible the same colour as that of the Pentane lamp, and the reading of a standard voltmeter connected across the lamp is carefully noted. The trolley is moved backwards and forwards until a balance is obtained, and a connecting rod is then clamped between the photometer head and the trolley, fixing their distance from each other. The Pentane lamp is extinguished after taking barometer and hygrometer readings.

The carbon lamp and photometer are moved away to the left-hand end of the bench and a trolley containing a Fleming substandard carbon lamp is placed on the right-hand side of the photometer. It is run at its rated voltage, and balance is obtained against the 8 candle-power lamp by adjusting the position of the Fleming lamp.

In this particular bench a little wheel connected with an endless string band is arranged about 150 cm. from the left-hand end of the bench. The trolley containing the Fleming lamp is attached to this band and its position may be adjusted by turning the little wheel. It is of course essential for the 8 candle-power lamp to be maintained at constant voltage throughout the test.

This process is repeated four times, using different Fleming lamps each time, and the Fleming lamps are then compared, one with the other, to check the accuracy of the readings. The only distances which have to be measured in this process are:

(1) The distance of the Pentane flame, and

(2) The distance of the Fleming lamp from the right-hand side of the photometer disk. This method of measurement will avoid errors due to the photometer head itself which, in the author's experience, are likely to be considerable.

LABORATORY MEASUREMENT OF CAPACITY, POWER FACTOR, DIELECTRIC CONSTANT, INDUCTANCE AND RESISTANCE, BY USE OF THE SERIES RESISTANCE BRIDGE. BY CLAUDE L. LYONS, M.INST.R.E.

(*Continued from p.* 160)

MEASUREMENT OF POWER FACTOR OR PHASE ANGLE

THE bridge is particularly adapted to the measurement of losses in condensers. This includes short lengths of power and telephone cables, fixed and variable condensers, waxes, oils, and samples of solid dielectrics only a few square inches in area.

Power factor measurement is made in the same manner as for capacity alone, except that note is taken of the change of reading of the decade resistance box, that is, the algebraic difference of readings at the two settings of the standard. By this method, it is the *change of losses* which is measured, making it unnecessary to know the losses of any of the condensers involved in balancing. To justify the assumption that the losses of the standard do not change with its setting it may be mentioned that the "G.R." Type 222 Precision Condenser employed has only six small pieces of carefully chosen insulation, and these are placed in a weak and unvarying electrostatic field. Therefore such a condenser may justifiably be considered as consisting of two condensers in parallel, one a perfect condenser, and the other a small fixed condenser having all the losses.

Having obtained the capacity of the condenser under test and the change of resistance when it was connected into circuit, the equivalent series resistance or power factor may be computed.

$$Rx = Rc\,\frac{(Cs)^2}{(Cx)} \qquad \ldots\ldots(1),$$

where Rx = equivalent series resistance;
Rc = change of setting of decade resistance;
Cs = capacity of standard condenser before the unknown was connected;
Cx = capacity of unknown condenser being tested.

From the value of Rx

$$\text{Power factor (P.F.)} = \tan\psi - 2\pi FCR \qquad \ldots\ldots(2)$$

(since ψ is small), where F = frequency;
C = capacity in Farads;
$F = Rx$ = equivalent series resistance.

Power factor or phase angle may also be read direct from curves furnished with the bridge, when Cx and Rx are known, and the total capacity of each arm is maintained at 1000 mmF. These curves are reproduced in Fig. 9.

Variation of capacity or losses with changes of temperature or pressure are readily followed, the observer taking the readings of the decade resistance and setting the standard condenser at as many points as may be necessary.

As an example of the use of this bridge for the measurement of the change of capacity and phase angle with change of temperature, mention might here be made of the following tests: A sample of hard rubber, three inches square by one-half inch thick was placed between two metal plates. At 54° F. this sample had a capacity of 11 mmF., and a phase

angle of 48′. When heated to 100° F. the capacity had increased to 12 mmF., and the phase angle to 1° 55′. This example clearly illustrates the extreme sensitivity of the instrument as regards the study of dielectrics under conditions of changing temperature.

If the capacity or power factor of a variable air condenser is to be measured, care should be taken to connect its low potential side to the *G* terminal of the bridge arm, and if the mounting case is of metal, it must be insulated from the earthed table-top. Unmounted variable condensers should be kept clear of all wires and outside dielectrics because of their large stray fields, which make for erratic results.

It may here be intruded that a good many manufacturers of variable condensers, and particularly those employed in broadcast receivers, do not quite understand what is inferred by "Power Factor." The resistance of condensers of equal merit, whether variable or fixed, depends on their capacity. Such is the "power factor" of condensers, and it is usually specified in percentage. A 1 per cent. P.F. infers that the loss of energy is 1 per cent. of all the energy supplied to the condenser.

Frequently the P.F. is designated by an *angle* of a certain number of degrees, minutes and seconds. This angle is the Angle of Phase Difference. This is an angle of which the sine is equal to the P.F. expressed as a decimal. In measuring P.F. neither of these is directly obtained, but the P.F. is computed from the equivalent series resistance:

$$\text{P.F.} = \frac{CR}{159} \qquad \text{......(3)},$$

where R = equivalent series resistance;

C = capacity of condenser in mF.

Despite all care taken in the manufacture of the bridge the same P.F. measurements will not be obtained if the standard condenser be employed in different arms—A or B of Fig. 1. This is due to minute variations of the losses at the connections and insulation in the respective arms of the instrument. It is, therefore, necessary to make a resistance-correction curve for the bridge. If this is not done it will be necessary, when doing P.F. measurements, to take the readings with the test condenser inserted first in one and then in the other arm, and the two results must then be averaged. The plotting of a resistance-correction curve, however, is simplicity itself, although perhaps a little tedious. In the long run, and especially if frequent P.F. measurements are to be undertaken, the making of such a curve is essential and it will result in saving much valuable time in routine work.

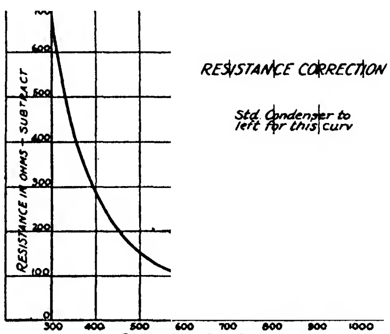


Fig. 7

Cx (Fig. 6) is replaced by any variable condenser. It is then adjusted to balance the standard condenser set at 300 divisions. The final balance of capacity is then made on C_1, and resistance balanced out at R_3. The two condensers are then interchanged and the bridge again balanced both for capacity and resistance. The difference between the two readings of resistance, divided by two, is the correction for that particular setting of the standard condenser in use. Corrections are similarly computed, say at every 100 scale divisions of the standard, and a curve similar to Fig. 7 results. As can be seen, the correction factor becomes negligible for the large capacities. If the bridge is in very frequent use a new resistance-correction curve may be needed each three or six months. The bridge should, therefore, be checked on the first working day of each month, to see if any changes in losses have occurred, which, if not taken into account, would result in inaccurate measurement of P.F.

Example of Power Factor Measurement. The sample measured (see Fig. 8) was a piece of hard rubber of the dimensions shown in the sketch. The bottom plate was the metal table

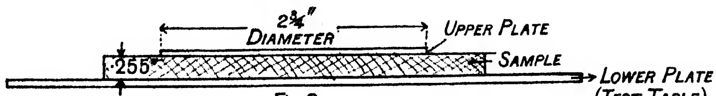


Fig. 8

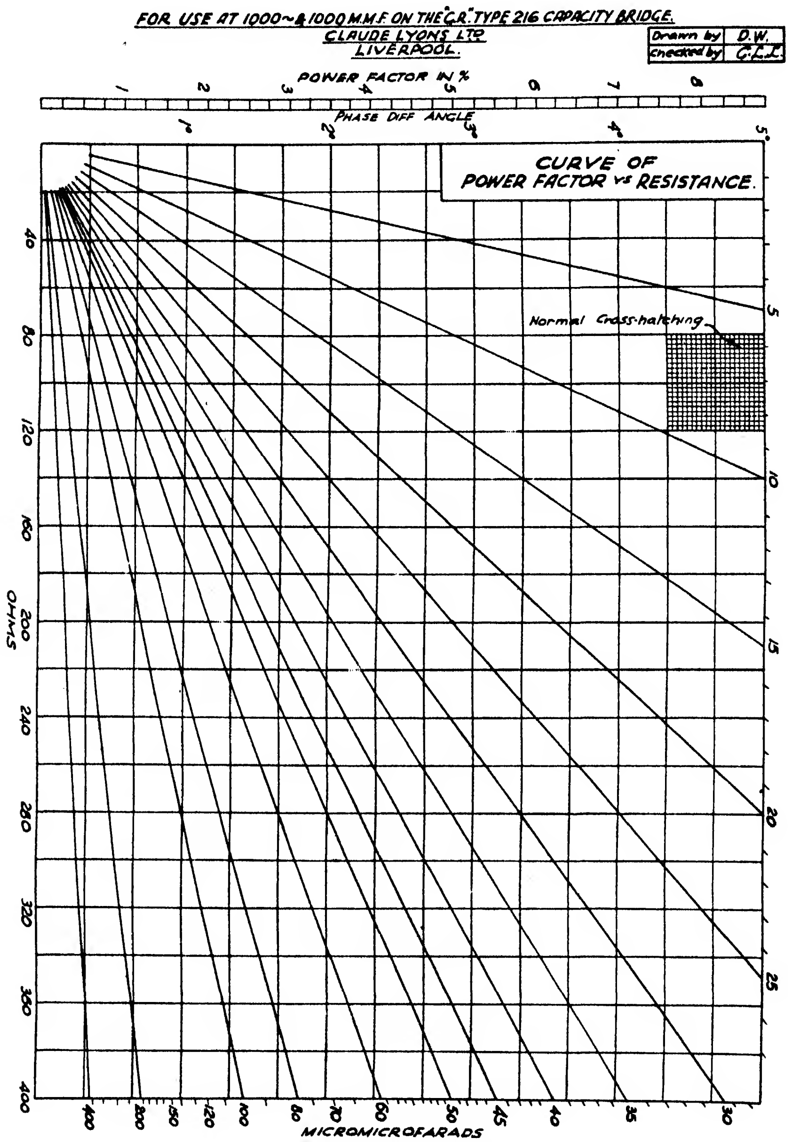


Fig. 9. (Reduced to half scale)

top described earlier, whilst the top plate was a brass disk $2\frac{3}{4}$ inches in diameter. The following was the procedure:

The bridge was balanced at 1000 mmF. (Cs) with the metal table top connected to the G of arm B; decade resistance reading was found to be 6 ohms in B. On connecting the top plate of the test condenser to the other side of the arm, these readings became 978 mmF. and 30 ohms respectively for the capacity of the standard and resistance in arm B.

From equation (1), we have

$$Rx = \frac{(1000)^2}{(22)} = 49{,}580 \text{ ohms.}$$

From equation (2), we have

$$\begin{aligned} \text{P.F.} &= 6283 \times 22 \times 10^{-12} \times 49580, \\ &= \cdot 00584, \\ &= \cdot 684 \text{ per cent.} \end{aligned}$$

This value may also be obtained from the curve sheet (Fig. 9) supplied with the bridge by the manufacturers, using ten times resistance (240 ohms) and dividing the 6·8 per cent. obtained by 10 to arrive at the correct power factor. This gives a more accurate result than could be had by using the 24 ohms. If desired the phase angle may be read at the same time, 23·4′.

Measurement of Dielectric Constant (K)

The dielectric constant of materials is obtained by placing a metal plate on either side of the insulator and measuring the capacity of the condenser thus formed.

$$K = \frac{Cx}{Ca} \qquad \ldots\ldots(4),$$

where K = dielectric constant;
Cx = capacity of test condenser;
Ca = capacity of similar air condenser.

The last item (Ca) refers to a condenser having the same plate area and same spacing as that of the test condenser, but with air dielectric, and is most conveniently computed, or rather read from the curve sheet furnished with the bridge for this purpose.

Unless the diameter of the plates is large in proportion to the thickness of dielectric, correction for fringing may be necessary. If the bottom plate is considerably larger than the top plate, the correction is made by computing the area of a similar air condenser with half the thickness of the dielectric added to the actual diameter of the upper plate, if it is round, or to each of two adjacent sides, if it is square or rectangular. When top and bottom plates are of the same size, the addition should be the total thickness of the dielectric.

Example of Dielectric Constant Measurement. The dielectric constant of the sample was determined as follows:

The area of the upper plate required is

$$\pi \frac{(D)^2}{2} = 3{\cdot}14 \frac{(2{\cdot}75)^2}{2} = 5{\cdot}93 \text{ sq. inches.}$$

Referring to Fig. 10, an air condenser having an area of 5·93 sq. inches and a spacing of ·255 inch is found to have a capacity of 5·4 mmF. (Ca).

From equation (4) $$K = \frac{22}{5{\cdot}4} = 4{\cdot}1.$$

If this constant is corrected for fringing we have the diameter (2·75 inches) plus half the insulation thickness (·127 inch) equals 2·88 inches, and the new area is 6·5 sq. inches.

$$Ca \text{ becomes } 5{\cdot}9 \text{ mmF., and } K = \frac{22}{5{\cdot}9} = 3{\cdot}7.$$

Had the bottom plate been the same size as the top, the diameter used for computing the area would have been 3·0 inches.

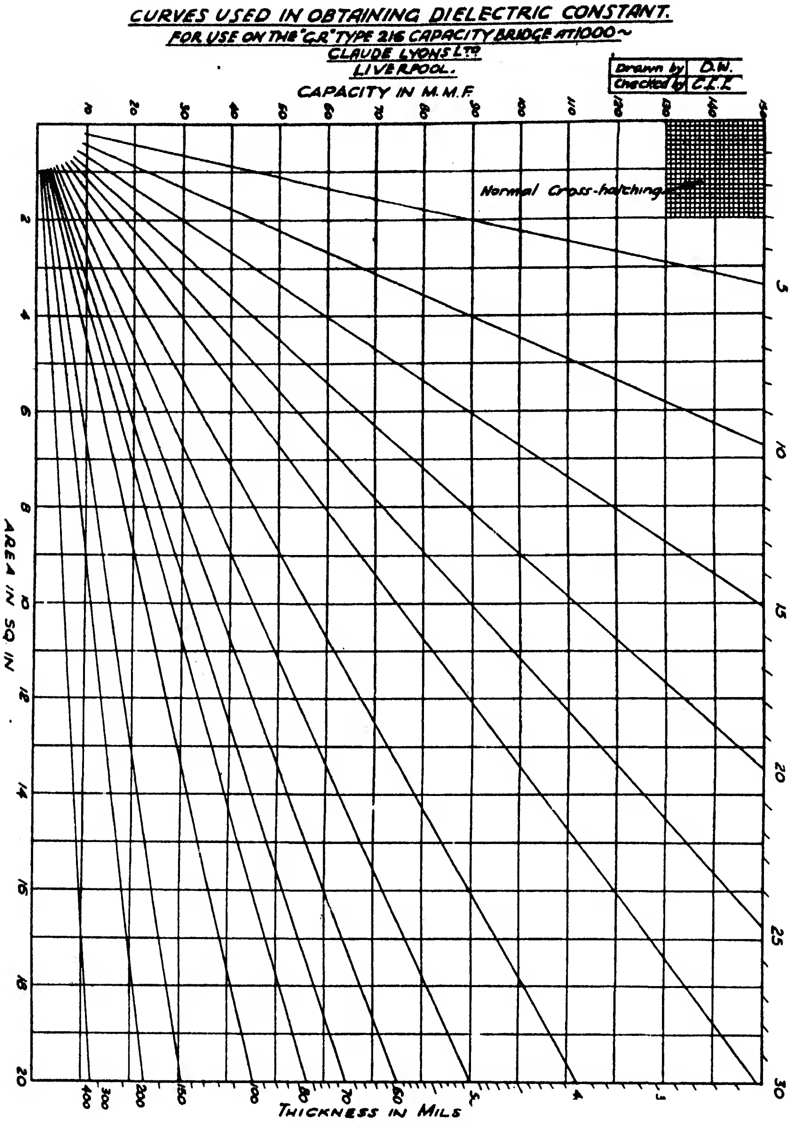


Fig. 10. (Reduced to half scale)

Variable Air Condensers

Variable air condensers are measured for losses in exactly the same way as the solid dielectric just described, but it is often necessary to know the resistance or power factor at several settings and this is obtained from one measurement, usually made the minimum capacity point, and other points computed from that. It should be stated emphatically that the bridge reading Rc is never the equivalent series resistance. This is shown by the following data, obtained when making measurements on a popular type of variable condenser sold for radio receivers:

$Cx = 25$ mmF. $Rc = 20$ ohms (readings at minimum capacity).

By equations (1) and (2), $Rx = 32{,}000$ ohms, and power factor is 0·5 per cent., provided the field through the dielectric *does not change*. The equivalent series resistance (Rx) is inversely proportional to the square of the capacity at any setting, therefore at the maximum

setting of 500 mmF., $Rx = 80$ ohms. The power factor is inversely proportional to the capacity; therefore, at 500 mmF. it is 0·025 per cent.

These figures show most forcibly that in comparing the merits of respective condensers, the capacity must be stated as well as the equivalent series resistance or power factor; *otherwise the comparison is meaningless.*

Measurement of Resistance

To measure resistance at 1000 ~ *, between values of 1 ohm and about 5000 ohms, two condensers are first balanced. The resistance to be measured (Rx) is then inserted into one of the arms, as shown in Fig. 11, and $R3$ and Cs are again adjusted to produce a balance. The difference between the two values of $R3$ is the value of the unknown resistance Rx. The condensers are necessary to prevent overloading of the oscillator when small resistances are used, and to balance out any inductance or capacity in the unknown under test. If a larger resistance than the decade resistance box incorporated in the bridge (5000 ohms) is to be measured, an additional standard resistance box must be used in series with $R3$. In this manner resistance measurements may be extended to about 10,000 ohms. An excellent decade box for use as such an additional adjustable resistance standard is the "G.R." Type 102–J., which is a four-dial instrument similar to that incorporated within the bridge itself, and which has series resistances of 10, 100, 1000 and 10,000 ohms, tapped as previously mentioned.

If measurements are desired having regard to a variation of frequency, this may readily be arranged by employment of a "source" of A.C. current of variable frequency. The "G.R." company produce a range of calibrated vacuum-tube oscillators, some of which are very suitable for such usage. It is important to remember that results are at 1000 cycles only when using the fork controlled oscillator, and the results may be vastly different with a change of frequency.

Measurement of Inductance

The same bridge set up is employed for the measurement of inductances as for resistances (Fig. 11). The capacity of a condenser is first balanced on the bridge, and the inductance coil, which is the unknown (Lx), is placed in series with this condenser. The bridge is rebalanced. The standard will show a larger capacity, and from this increase in capacity the inductance of Lx is computed:

$$Lx = \frac{C2 - C1}{39{\cdot}5 \times C2 \times C1} \qquad \ldots\ldots(5),$$

where $C1$ = initial capacity of the standard in mF.
$C2$ = final capacity of the standard in mF.

Thus, if $C1 = {\cdot}0010$ mF., and $C2 = {\cdot}0011$ mF.,

$$Lx = \frac{{\cdot}0011 - {\cdot}0010}{39{\cdot}5 \times {\cdot}001 \times {\cdot}0011} = 2{\cdot}3 \text{ Hys.}$$

This method of measuring inductances is based on the principle that if the inductive is smaller than the capacitative reactance, and the two are connected in series, the combined result is the same as would be obtained by one condenser of larger capacity.

* It must be borne in mind that these measurements are taken with a small current flowing, and at 1000 ~. Most resistances change somewhat with frequency and current.

To use this method successfully, therefore, the choice of capacity should receive some consideration. It must not be too large. If too large, the net reactance in the lower arm will become *inductive* and therefore cannot be balanced by a *capacity* in the upper arm. If too small, $C2 - C1$ will become minute and accurate results will be unobtainable. It has been found that ·001 mF. is suitable for inductances from about 0·4 to about 4 Hys. For smaller inductances, larger capacities should be used, and *vice versa*. This is obvious if the values of C and L are thought of as capacitative or inductive reactance. When uncertain of the approximate value of the unknown Lx, it is best to try a capacity round about 220 mmF. (suitable for measuring inductances of round about 25 Hys.). If the difference in the capacity readings is *small*, on rebalancing the capacity should be *increased*, in large steps such as 200 mmF., 1000 mmF., 10,000 mmF., and 100,000 mmF. The last value (0·1 mF.) will suffice for the accurate measurement of inductances as small as a fraction of one millihenry.

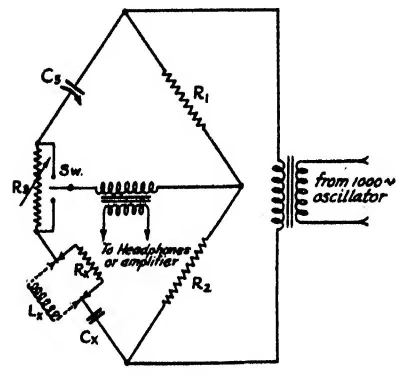


Fig. 11

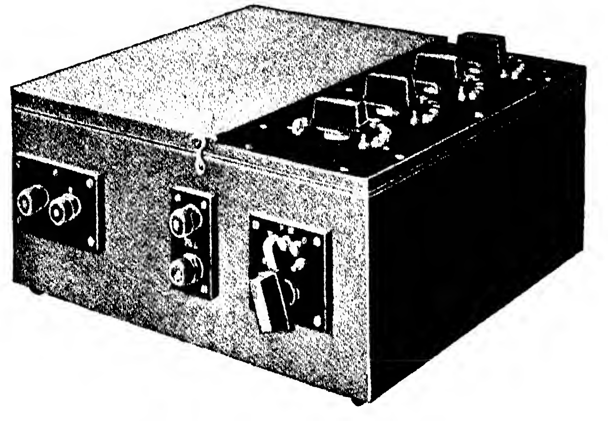


Fig. 12. External appearance of the "G.R." Type 216 Capacity Bridge

Again, it must not be forgotten that these inductance measurements are being made at 1000 ~, and with a small current flowing. As with resistances, there is a change with current and frequency change, and, furthermore, these changes are far more serious in regard to *inductances*. There is very little doubt that this is not clearly understood by many present-day manufacturers of radio components and accessories. As an example, the inductance of an iron-cored choke coil such as might be built into a choke-condenser filter combination in a "high tension eliminator," will have a certain inductance value with, say, a small 50 ~ or 1000 ~ current flowing in its windings: but with 40 or 50 milliamperes flowing, plus, perhaps, 1 or 2 mA. A.C. in addition, this inductance will be a very considerably smaller value. Failure to grasp this well-known fact is clearly responsible for the dismal failure of many quite well-known high tension units of this type (and especially those turned out for use on alternating current mains), to work well under actual working load.

Fig. 12 shows the external appearance of the Bridge described.

NEW INSTRUMENTS

A NEW INTERNAL-FOCUSSING TACHEOMETER.

By W. H. CONNELL.

The modern demand for light and more compact surveying instruments has called forth some remarkable developments recently, and in this article information is given regarding a new internal-focussing anallatic telescope which is the subject of a patent taken out in the joint names of Mr E. W. Taylor and Messrs Cooke, Troughton and Simms, Ltd. The telescope referred to is now fitted to the tacheometers made by that firm.

In the past "Cooke" and "Troughton and Simms" tacheometer telescopes have incorporated the Porro anallatic optical system, which refers all tacheometric measurements to the centre of the instrument. This system cannot be embodied satisfactorily in a telescope of constant length, and therefore attention has lately been directed to the problem of producing a telescope having a negligible stadia constant and constructed on the lines of the internal-focussing type. The advantages of the latter may be summarized as follows:

(*a*) The overall length is constant. The telescope therefore may be hermetically sealed; dust and moisture being thereby excluded.

(*b*) The focussing of near objects does not appreciably disturb the balance of the telescope since the focussing lens is situated between the object-glass and the eyepiece.

(*c*) The constant length of the telescope and the simple nature of the focussing device render possible a greatly improved mechanical design, which ensures the focussing lens moving truly along the optical axis. Thus collimation errors of practical importance are non-existent.

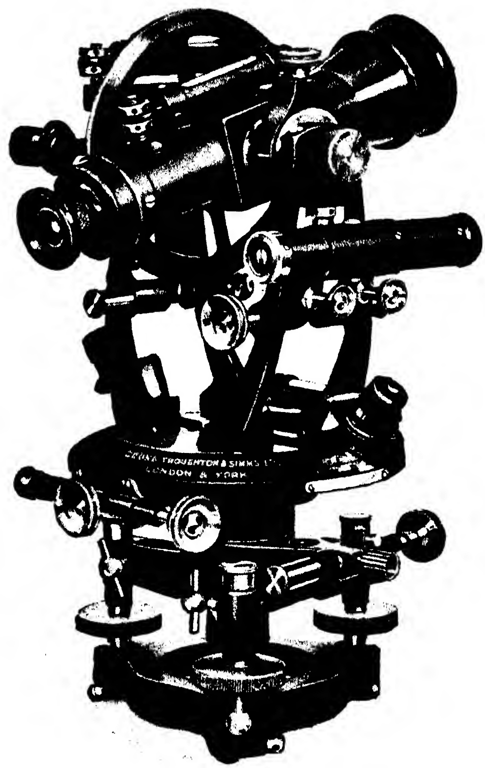


Fig. 1. The 4½″ Tacheometer

Up to the present this new optical system, which has an aperture ratio of *f.* 4, has been produced in two sizes, viz.:

(i) 1·65 in. clear aperture, measuring only 8 in. overall length, fitted to tacheometers having circles of 5 in. dia.

(ii) 1·5 in. clear aperture, measuring only 7½ in. overall length, fitted to tacheometers having circles—horizontal 4½ in. dia., vertical 4 in. dia.

Fig. 1 illustrates the smaller instrument and incidentally shows how the improved trough compass, referred to in detail later, is mounted and observed. It illustrates also that the advantages of robustness and great telescope power (which for so many years have characterized the best British types of instruments) are retained, whilst dimensions and weights have been considerably reduced.

It will be sufficient to give precise data regarding one size only, and with regard to the telescope having an objective of 1·5 in. dia., it may be stated that its focal length is 6 in., and that it is self-corrected for spherical and chromatic aberration, also for freedom from coma or side flare. The focussing lens (see Figs. 2, 3 and 4) is of 6 in. negative focal length and is also fully self-corrected. This leads to a marked improvement in the definition at short distances (a point of special importance to mining engineers) as the combination is fully corrected at all settings, and aberrations are not introduced by the focussing lens, as is the case in the more usual patterns of internal-focussing telescopes.

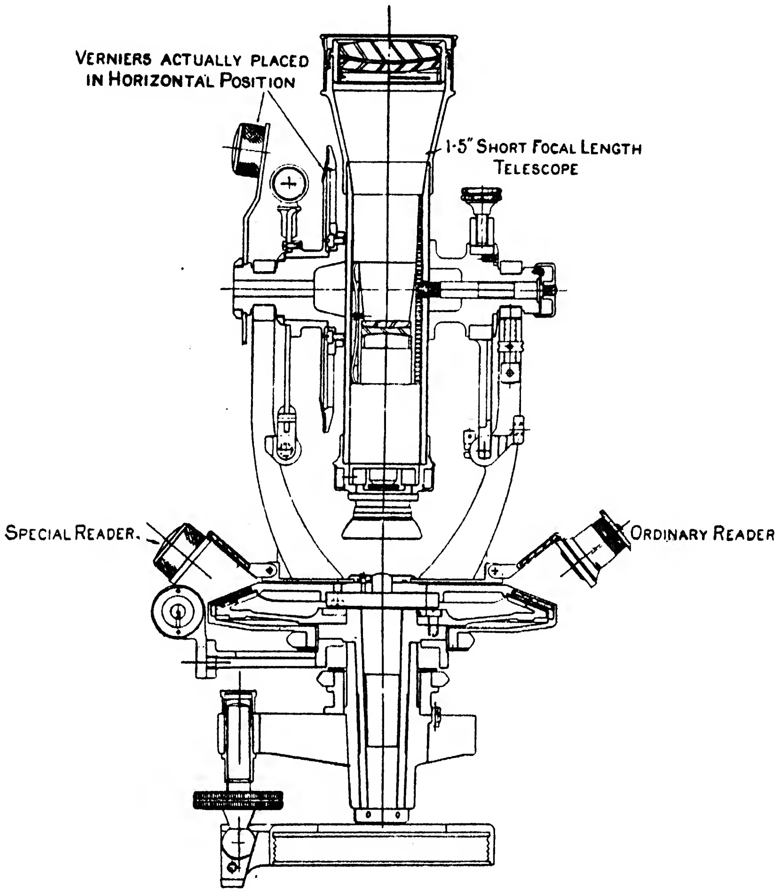


Fig. 2. Construction of 4½" Tacheometer

It is obvious that the objective and focussing lens, being of equal power, would have exactly equal and opposite effect were it not for their separation of 4·25 in. at stellar focus. Actually the focal length of the combination has always a value equal to the square of the focal length of the objective or focussing lens divided by the separation between them, and at stellar focus this combined focal length is 8·47 in. This special relationship, which gives rise to an almost perfect anallatic telescope, is the subject of British Patent No. 242468.

If, as is usual in internal-focussing telescopes, the objective and focussing lens are of different powers, it follows that the first principal point of the combination to which all object distances are referred, and the second principal point of the telescope to which all image distances are referred, take up different positions along the axis according to the distance of the object focussed, but when, as in the present telescope, the objective and

negative lens are of equal but opposite power the first principal point is fixed in space and made quite independent of the focal setting, while the second principal point maintains always a fixed position in respect of the movable focussing lens. The problem of securing that all distances deduced from the stadia intercept are referred to an anallatic point situated at the point where the vertical and horizontal axes of the telescope intersect is much simplified, and though a slight movement of the anallatic point does take place and can only be entirely prevented by the introduction of a further lens, the errors arising from this cause never exceed one part in a thousand for all sights over 12 ft. distant.

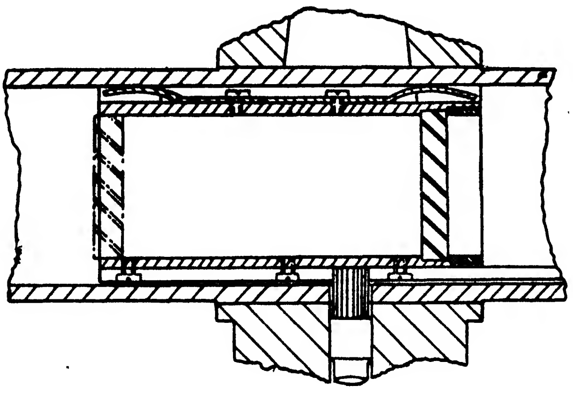


Fig. 3

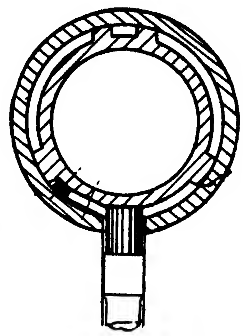


Fig. 4

Figs. 3 and 4 give details of the mount which carries the focussing lens, and it will be noticed that it makes contact with the interior walls of the telescope body-tube at three points, one of which is a long spring designed to take up loss occasioned by wear from long-continued use. The rack and pinion are kept in engagement by another spring which results in an exceptionally smooth mechanical movement. The objective cells are interchangeable and have a plain fitting which allows their removal when necessary without fear of disturbing the collimation adjustment, as is inevitable when threaded cells are used. The lenses fit accurately in their cells and are prevented from turning by the use of a cement which also effectively excludes moisture. The use of mandrel-drawn tubing in the telescope has been discarded and the body-tubes and end fittings are machined straight and cylindrical, with an accuracy of 0·0001 in., out of duralumin. Balsamed surfaces have been eliminated from the object-glass.

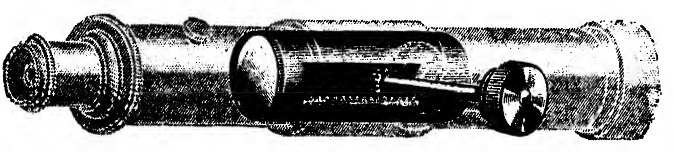


Fig. 5

The eyepiece has been specially designed on Kellner lines for this internal-focussing telescope, and a large angle of view with exceptionally flat field has been obtained. Ebonite eye-shields are fitted. Another noteworthy improvement (shared with Messrs Casella) consists of the removal of the focussing head from the old position either at the eye end or object-glass end of the telescope, and it is now placed at one extremity of the transit axis, as shown in Fig. 5. Arranged thus it is always ready to hand no matter what the position of the telescope may be.

With regard to the diaphragm, lines ruled on glass are standard, though webs are supplied if asked for. The stadia lines are spaced with an accuracy of 0·0001 in. As shown in Fig. 6, the graticule *B* is readily removed (by the use of tool *A*) for cleaning purposes or interchanging, and that with a maximum disturbance of collimation of 2 seconds of arc. A spare diaphragm is provided against emergency.

For those prepared to pay the slight extra cost an improved magnifier for reading the verniers is available; see Fig. 2. It consists of an achromatic doublet giving a flat field free from colour and distortion.

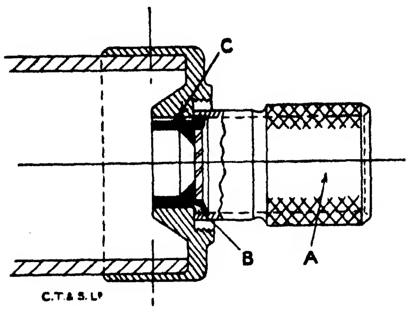


Fig. 6

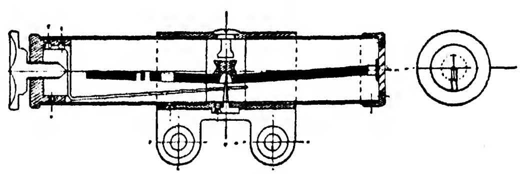


Fig. 7

Among other interesting points of design embodied in the tacheometer it should be noted that the vertical axes or conical centre of the instrument, after being turned as perfect as possible, are bedded together by hand scraping, *i.e.* without grinding. Thus no abrasive is introduced into vital fittings whose permanent accuracy is of the greatest importance. Practical surveyors, especially those operating in localities far removed from a repair shop, will note with interest that the metal mounts of the spirit levels are interchangeable, though the vials thus differ in sensitiveness, of course.

The improved trough compass is illustrated in Fig. 7, which, when required, is attached solidly by screws to the instrument (see Fig. 1), which arrangement practically eliminates index error. The south end of the needle is read to within 5 minutes of arc against an index mark on the glass window closing the end of the tube. The tubular construction renders the compass dirt-proof and wind-tight.

A NEW ELECTRICALLY OPERATED CHRONOSCOPE.

By D. C. GALL.

This instrument has been developed by Messrs H. Tinsley and Co., Werndee Hall, South Norwood, S.E. 25, to meet the need for a simple device for measuring the operating times of automatic telephone relays. It consists of a constant speed motor driving a friction disk, into contact with which a jockey-wheel is brought under the influence of an electro-magnet. The jockey-wheel is directly connected to the pointer, which indicates the time during which the jockey-wheel is in contact with the disk.

The mode of operation is similar to that of Dr Wood's and Mr Ford's chronoscope, but the design is considerably modified. For example, the tuning fork and phonic motor have been dispensed with and a constant speed D.C. shunt wound motor is used. This motor is fitted with a governor which compensates for voltage changes in the supply. It is intended that the chronoscope should be driven from the exchange 50-volt battery while carrying

out tests, and this, in conjunction with the governor, is sufficiently steady to maintain the requisite degree of accuracy.

The operating magnet system is of a type which allows of very rapid movement of the jockey-wheel, so that intervals of a few milliseconds can be recorded. Great accuracy is not

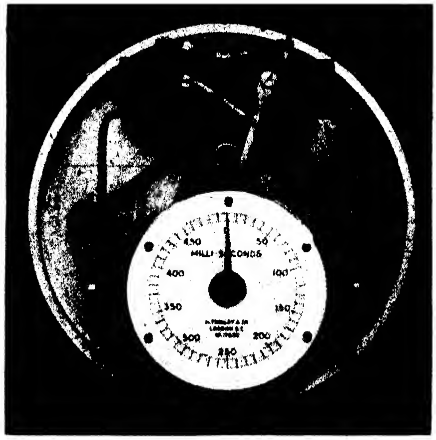


Fig. 1

Fig. 2

necessary, and about $\frac{1}{2}$ per cent. is aimed at. The dial has only one pointer and reads up to 500 milliseconds for the complete revolution. This pointer is provided with an electrical resetting device operated by an external key. The operating magnet can be wound differentially or arranged to indicate successive impulses. The instrument is illustrated in Figs. 1 and 2.

CORRESPONDENCE

MISTUNING OF WEIGHTED FORKS

My attention has been drawn to a paper in this *Journal* by Prof. W. R. Miles "On the Mistuning of Weighted Forks"*. I think most users of electrically maintained forks are familiar with the points raised by Prof. Miles and would agree that "unbalancing" is the more correct term to apply in certain cases which are sometimes quoted as "mistuning."

* May 1928.

In ordinary U-shaped tuning forks the two prongs are "tightly coupled" (to use the analogous electrical term) via the stem or point of clamping, and must consequently vibrate at the same frequency. What this frequency is depends on the degree of coupling and on the frequencies of the prongs vibrating independently. For very tight coupling the resulting frequency is either equal to $\sqrt{N_1 N_2}$ or to a very high frequency—the former being most probable. Lack of balance between the prongs manifests itself in increased vibration of the point of support. This vibration is transmitted to the base of the fork and its surroundings, with consequent dissipation of energy. The vibrations of the fork therefore die away more rapidly the greater the "out of balance."

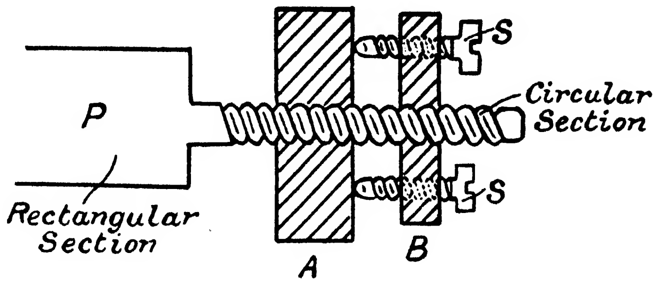


Fig. 1

A convenient way of testing the balance of a fork having adjustable loads is described in my paper in this *Journal**. Fine adjustment of balance and tuning is obtained by dividing each load into a large portion A and a small portion B, each *screwing* independently on the end of the prong P. The two parts A and B are locked together, and to the prong, by small screws s (see Fig. 1). If the thread on the prong has a moderately fine pitch, a fraction of a turn of B represents a relatively small movement in the position of the centre of gravity of the total load.

This type of adjustable load is shown in Fig. 4 of a paper by the writer and Mr J. M. Ford in this *Journal*, Vol. 1 (1924), p. 167.

A. B. WOOD.

ADMIRALTY RESEARCH LABORATORY,
TEDDINGTON, MIDDLESEX.

RECENT RESEARCHES AT THE NATIONAL PHYSICAL LABORATORY

The National Physical Laboratory. Report for the Year 1927. Pp. vi + 264. London: H.M. Stationery Office. Price 7*s*. 6*d*. net.

[The reviewer will give, in this and following months, an account of recent researches at the National Physical Laboratory, based on the Report for the year 1927, and dealing with each of the Departments in turn.]

PHYSICS DEPARTMENT

Determination of Flame Temperature by the Reversal of Spectral Lines. An investigation has been made of the method of measuring flame temperatures based on spectrum-line reversal. In the arrangements used the image of the tungsten sphere in a "Pointolite" lamp was focussed through the flame on to the slit of a spectroscope. Sodium was introduced into the flame, and when the temperature of the flame was greater than that of the tungsten sphere, bright sodium lines showed

* 1 (1924) 330.

up on a continuous spectrum background. If the temperature was lower, the sodium lines were reversed. By adjusting the temperature of the tungsten sphere, a point was reached when all trace of either bright or dark lines disappeared. This balance could be effected easily within a range of a few degrees. The corresponding temperature of the sphere was then found by an optical pyrometer.

The first question studied was the influence of flame thickness, and it was found that the method gave results independent of the thickness of the flame. In another experiment both sodium and lithium salts were sprayed in the gas supply to the burner, and the red and yellow lines were also obtained simultaneously by using a solution of both salts in the spray. It was found that the temperatures obtained were the same whether the red or the yellow lines were employed as indicators. By vaporizing sodium chloride in a carbon tube furnace and determining the temperature of the vapour by the reversal method it was found that the radiation from the vapour was purely thermal in origin. The spectrum-line method has found practical application in the determination of the temperature of a carbon-monoxide flame burning in oxygen. A noteworthy feature of this method is that it is devoid of "time lag" and so, for example, may prove of value in measuring temperatures in the explosion cycle of an internal combustion engine.

Optical Pyrometer Scale. The work on the melting point of palladium has been continued. The object aimed at is the realization at the temperature of melting palladium of a black-body radiator to be obtained by immersing a closed-ended and suitably diaphragmed tube in an ingot of the metal. By sighting into the tube with an optical pyrometer when the ingot is held at the melting point, it is possible to measure the brightness of a black body at the melting point of gold, and hence to determine the melting point of palladium relative to that of gold.

On the grounds of expense, preliminary work was carried on with specimens of nickel, which melts about 100° C. lower than palladium. Two types of furnace have been employed, one of which was similar to that used by Hoffman and Meissner. In this case the heating element consisted of platinum foil, 0·0015 inch thick, made up into the form of a cylinder about 15 inches long and 3 inches in diameter. This element was suitably lagged and was found to require a current of about 350 amperes for a steady temperature of 1600° C. The other furnace was of the induction type, employing valve-maintained oscillations of high frequency. In both furnaces ingots of nickel about 1 kilogramme in weight were melted, and experience was gained in the taking of melting and freezing curves by the optical pyrometer.

High Frequency Induction Furnace. The furnace has been made for the melting of metals of high melting point *in vacuo* or in a controlled atmosphere. A charge of 1200 grammes of palladium has already been melted. The furnace has been designed to handle 12–16 kVA, although up to the present the limitations of the available power supply have prohibited the use of more than about 10 kVA The choice of circuit for the oscillator was governed by the requirements of reliability, safety in operation, flexibility and simplicity, especially simplicity of the inductor coil surrounding the furnace charge. The well-known Hartley circuit, employing a centre-tapped coil, fulfils all these conditions and was therefore used. The "parallel-feed" system ensures safety in operation, since the furnace coil itself is at earth-potential as regards low frequency potentials, and the high frequency potential developed across it is not dangerous.

The selection of a suitable frequency presents some difficulty, and published theoretical papers are by no means in agreement. Modern practice is to employ comparatively low frequencies, from 500 cycles per second in the case of some alternator furnaces, to 80,000 cycles in the Northrup furnace. With lower frequencies it is necessary to use correspondingly larger condensers, and this is an important consideration. There is, however, evidence that much higher frequencies are not detrimental, and the present furnace has been designed to operate on a frequency of 800–1000 kilocycles.

Dew Deposition Recorder. In certain experiments made by the Food Investigation Board on the storage of apples, it was desired to have the means of recording the number of times dew deposition had occurred on the fruit during storage. An instrument has been devised for this investigation, the design of which is as follows:

Two coils are wound on a former ring which can be slipped on an apple. Alternatively the former may be made in the form of a glass dummy apple adjusted to have a heat capacity equivalent to that of an apple of the same size. The two coils are wound of enamel-insulated wire, and the enamel is removed from the exposed surface by fine glass-papering. The coils have adjacent turns arranged so that a deposit of dew bridges the two circuits and permits a current to flow when a suitable potential difference is applied between the two coils. Electrolytic polarization is avoided

by continued rapid reversals of the current by a relay system. A moving-coil recording instrument indicates the flow of current between the coils. The record takes the form of a broad band traced out by the vibration pencil during the period.

Industrial X-ray Crystal Analysis. A new section was created during the year to investigate, on behalf of the Research Department, the application of the methods of X-ray crystal analysis to industrial problems, and has begun work on certain problems. The question which has received chief attention has been that of the structure of tungsten steels, having regard more especially to their use as permanent magnets. The steels so far examined have been 6 per cent. tungsten steels containing 0·7 per cent. of carbon. Attention has been directed largely to the investigation of the changes in the X-ray diffraction patterns which accompany different heat-treatments, in particular the heat-treatment that results in the spoiling of the steel from a magnetic standpoint. The results of the preliminary investigation showed that the water quenching of this steel from 850° C. caused the appearance in the X-ray photographs of a group of lines other than the α-iron lines. Continued heat-treatment at 950° C. resulted in a marked improvement in the definition of these lines, most probably due to an increase in the size of the crystals to which they owe their origin. This heat-treatment is one which results in a serious drop in the value of the coercive force of the steel. A short heating at 1250° C. with subsequent air cooling caused the disappearance of these lines and showed practically only the iron lines. When the steel so treated was water quenched at 850° C. the result was the reappearance of the lines with a definition similar to that found in the original quenched specimens. This treatment of the spoiled steel gives once more a steel of good magnetic quality.

Transmission and Reflection of Sound by Test Partitions. Work has been continued during 1927 on the transmission and reflection of sound by test partitions clamped over an aperture in the wall between two sound-proof rooms. In this method a beam of sound is directed obliquely against the partition from one side, and, by means of suitable microphones, measurements of sound intensity are made in the reflected and transmitted beams. It had previously been found that the interference pattern of the sound in the transmission room was the same with felt-like partitions over the aperture as with the aperture uncovered, the transmission ratio being largely independent of the position of the point at which it was measured. Thus the beam was not dissipated on transmission.

Experiments have now been carried out with board-like partitions to see whether the beam would be modified by the membranal vibration of the board set up by the action of the sound beam. It was found that, although transmission ratios varied rather more from point to point than was the case with felt-like partitions, they were still largely independent of the position at which they were measured. Large partitions such as those used have low natural frequencies, and it appears that the effect of such a partition is to reduce the intensity of sound transmitted without markedly affecting the extent of the beam. Even with a 2-inch partition of solid mahogany there was always a definite beam of transmitted sound, the intensity of sound at points off the line of the original beam being comparatively negligible.

Work with a double board partition in which the two members were structurally quite separate also gave results largely independent of the position of measurement.

Work was then conducted with a microphone swinging in the sound beam. It was found that the swinging microphone satisfactorily averaged the intensity at the points in its path, and that the adoption of a moving microphone should reduce the time and labour of point-to-point explorations.

Small Scale Measurements of Acoustical Absorbing Power. Further attention has been given to the measurement of absorbing power of materials by the stationary wave method. In the work a small circular disk of the test material, 6 inches in diameter, is employed. This disk, cemented to a thick steel plate, is used to close one end of a smooth cylindrical sound tube having rigid walls. The other end of the tube is open and faces a steady loud-speaker source of sound emitting a pure note of known pitch. Sound waves from the source pass along the tube and are reflected by the specimen to an extent depending upon the absorbing power of the material. Interference between the incident and reflected sound results in a system of stationary sound waves in the tube, *i.e.* a series of positions of maximum and of minimum sound intensity, the relative magnitudes of which depend upon the fraction of the incident sound energy absorbed by the material. Relative measurements of the maxima and minima of sound intensity are accordingly made, using one end of an exploring tube which passes out of the test pipe to a suitable microphone. From the results the sound absorption coefficient of the material is calculated.

The Analogy between Ripples and Acoustical Wave Phenomena. There has been some improvement of technique in the use of the ripple tank for the study of acoustic phenomena. For convenience and low cost it is essential, where single impulse ripples are concerned, to get good photographs of the ripple image on the translucent screen when using an ordinary camera. There are conflicting requirements; the exposure must be sufficiently short so that the moving ripples shall not be blurred, and long enough to give adequate exposure. Using an arc with a reasonable current of 20 amperes for illumination, and increasing the intensity about ten-fold by using a condenser, good results are obtained with an exposure as long as 1/75 second with the lens stop at $f/6{\cdot}3$, when ordinary plates (H and D 70) or process plates (H and D 25) are employed and developed with hydroquinone.

Certain photographs have been taken illustrating the behaviour of a Quincke filter when applied to a speaking tube, and a filter effect which occurs in wave transmission through a curved conduit.

Investigations of Optical Systems. A considerable amount of work has been done during the year on the new Hilger universal lens interferometer. A series of interferograms taken with a triple telescope objective to illustrate, for an inclination of 5° to the axis, the change in the interference pattern as the focus is altered between the focal lines, was shown at the Exhibition of the Royal Photographic Society, 1927. The photographs showed clearly the passage from elliptical fringes with major axes horizontal, through systems of hyperbolas, to ellipses with major axes vertical.

In modern photographic lenses, as in other optical systems, the standard of definition falls off continuously as the angle with the axis is increased. On the interferometer this is shown by the gradual increase in the number of the interference fringes. In the outer parts of the field these become so crowded, even at the best focus, that it is difficult, and often impossible, to count them in a visual examination. In the presence of aberrations their clearness also falls off, and, when the aberrations reach sufficiently great values, the variations in light intensity in the fringe pattern become too small for any fringes to be distinguished. It is found that this condition is reached at about the same part of the field as causes the breakdown of the older visual tests owing to the non-recognizability of the image.

Asymmetrical Lens Systems. With regard to astigmatic effects of the eye, and their correction by spectacles, it is found that the error due to the rotation of the image about the axis of the eye cannot be corrected. This defect may prevent an observer from attaining the highest accuracy in placing two parallel lines so as to form one continuous straight line. Such settings are called for in the use of various optical instruments, the coincidence range-finder being a well-known example. In the use of such instruments it is found that certain observers easily attain a degree of accuracy which is completely beyond the power of others, whose sight nevertheless appears to be free from defects. It may be noted that an eye may have all its surfaces astigmatic, but so related that the eye as a whole is free from astigmatism, and yet possess a distinct amount of this secondary rotation of the image space relatively to the object space. Defects of this type will, it is anticipated, produce an appreciable effect whenever rotation of the eye in its socket plays an essential part in making precise settings.

Accuracy of Optical Settings. The work which has been in progress during the past three years on the setting of diagonal cross-wires has been completed, and a paper has been prepared dealing with the influence on sensitivity and personal equation of such factors as thickness of wires, inclination of the diagonal wires, and brightness of field. The results should be of general interest to designers of optical instruments.

Focometric Tests. A request was received from France for the measurement of the focal length of a lens with the aperture cut down to 8 mm., the accuracy required being one part in two thousand for a focal length of about 5 cm. The lens was sent to the Laboratory because no apparatus exists in France capable of giving the accuracy mentioned, which represents a precision appreciably greater than the physical character of light enables us to obtain under ordinary conditions. The work was accepted as an incentive to the attainment of a high degree of precision in such measurements, under the most difficult conditions. A series of measurements was made by a special magnification method, each agreeing with the mean to one part in eight thousand. R. T. B.

(To be continued.)

REVIEW

British Research Association for the Woollen and Worsted Industries. Torridon, Headingley, Leeds. Annual Report, 1927–28.

The Annual Report of the British Research Association for the Woollen and Worsted Industries records a year of progress and considerable extension of the activities of the Association, and gives ample evidence of the importance which is attached to its work by those in whose interests it is conducted.

A reference in the Report to the methods proposed for financing the future work of the Association is of the greatest interest. The proposal, with regard to which negotiations are proceeding with the Trade Federations, is a statutory levy on all raw wool consumed in this country. It is stated that a levy on such a small scale as one-hundredth of a penny per pound would provide an income of £20,000 a year; and the British Wool Federation have indicated that, subject to certain conditions, they are prepared to consider sympathetically co-operation with the Association for the purpose of collecting the levy. This would appear to be a new departure in methods of financing industrial research in this country, and the fact that such a proposal is under serious consideration is proof that, in this at least of the staple industries of the country, the manufacturers are fully alive to the importance of scientific research. It is to be hoped that such a broad-minded attitude to science will find extension to other industries.

On the recommendation of the Empire Marketing Board a special Government grant is being made to the Association, to cover capital expenditure up to £7000 and maintenance up to £2000 per annum for five years, for research on problems connected with the standardization of raw wool, to be carried out in conjunction with Dr F. A. E. Crew, Director of the Animal Breeding Research Department of the University of Edinburgh. Steps to secure the co-operation of the wool-growing Dominions are announced.

The Report records additions to the staff and extension of premises in connection with the grant from the Empire Marketing Board, and for other purposes. Laboratories for microscopic and bacteriological work have been added and Colour Laboratories have been instituted for extensive investigations in relation to the fastness of dyestuffs. Other researches and enquiries are concerned with improvements in wool breeding and with the discovery of a suitable material for sheep branding. A list of extra-mural researches is given, carried out in University and other laboratories, in conjunction with the staff of the Association. A number of these are concerned with experimental methods and instruments, for example, on the transmissive power of glass screens, in the Clarendon Laboratory at Oxford; on spectrophotometric investigation of fading of dyestuffs, on development of the mutochrome for textile purposes, and on the colour comparator, in the Research Department of Adam Hilger, Ltd.; on a fibre comparator, on an automatic humidity control, and on the measurement of diameter of woollen and worsted yarns, in the Research Department of the Cambridge Instrument Company, Ltd. The Technical Department at Torridon investigates trade problems for the members, and over 300 such problems have been dealt with during the year.

Appendices to the Report give the publications of the Association and also its list of members. The latter comprises no less than 395 names, nearly all of firms engaged in the different branches of wool manufacture, and is itself a testimony to the support the Association receives from the manufacturers.

T. M.

THE ROYAL SOCIETY

A NUMBER of interesting exhibits were shown at the Royal Society's Conversazione at Burlington House on May 17th. These included a High Temperature Electric Resistance Furnace from the National Physical Laboratory (Dr W. Rosenhain, F.R.S. and Mr W. E. Prytherch) in which the heat is generated in the resistors by contact resistance between pieces of carbon or graphite. The novel feature of the resistors is that the short cylindrical pieces of graphite, placed end to end, are protected from oxidation by being enclosed in a loosely fitting refractory tube or sheath, sufficiently impervious to prevent rapid diffusion of gases. There is thus no appreciable burning even after weeks of exposure at temperatures as high as 1300° C.

The Cambridge Instrument Company showed an ingenious Apparatus for the Measurement of the Diameter of Fine Quartz Fibres. This consists of two jaws, one fixed and the other movable, between which the fibre is placed. The movable jaw is connected to a jointless lever system carrying at its end a platinum contact, motion of the jaw resulting in a proportional and greatly amplified lateral motion of the contact. This contact completes an electrical circuit through another similar contact, which is attached near the fixed end, at about one-tenth of the full length from it, of a long helical spring. The spring is extended by hand rotation of a spindle to which is attached a pointer moving over a scale, and the moment of making or breaking contact is indicated by the deflection of a galvanometer. A measure of the diameter of the fibre may thus be obtained on the scale. It is stated that the device is capable of measuring fibres of from 20 microns downwards; and that readings can be repeated to within 0·25 microns.

Interesting experiments were shown by Sir William Bragg, F.R.S., who reproduced one of Faraday's experiments showing the crispations or undulatory patterns formed on liquids lying on flat vibrating surfaces; and by Dr D. W. Dye, F.R.S., who showed the interference patterns produced under illumination from a mercury vapour arc by a quartz plate, vibrating Piezo-electrically, with a flat glass surface supported close above and approximately parallel to it.

Mr George H. Gabb showed an exhibit of historic interest which he claimed to be the earliest known theodolite. The instrument is of brass, signed and dated "H. Cole, 1574." It consists of a circular base plate, 6¾ in. diameter, divided into single degrees and numbered in tens, 10 to 360. The circle is sub-divided into half degrees on the bevelled rim; and an inner circle is divided quadrantally, with divisions of 10 degrees numbered 10 to 90. Within these circles is a "Geometricall Square"; and within the square again is a compass "card" inscribed with the 32 points. The index by which the horizontal reading is taken is fitted with two lugs, to which are attached the case enclosing the compass-box and carrying the supports for the vertical semicircle and plummet. An interesting point is that a plate in the compass-box has engraved upon it a compass needle indicating the magnetic variation—11° E.—for the date of manufacture of the instrument. The vertical semicircle, which is provided with vanes for sighting and divided in degrees, is stated to be restored.

THE INSTITUTE OF PHYSICS

ANNUAL GENERAL MEETING

THE ANNUAL GENERAL MEETING of the INSTITUTE OF PHYSICS was held in the rooms of the Institute at 1 Lowther Gardens, S.W. 7, on May 15th. The following were elected to the Board for the year 1928–29, to take office on October 1st, 1928:

President, Sir Frank Dyson; Vice-Presidents, Dr Alexander Russell and Mr C. C. Paterson; Honorary Treasurer, Major C. E. S. Phillips; Honorary Secretary, Professor A. O. Rankine; Non-official Members of the Board, Dr Norman R. Campbell and Professor C. L. Fortescue. Other new members of the Board were Dr Allan Ferguson, nominated by the Physical Society, Mr R. G. K. Lempfert, nominated by the Royal Meteorological Society, and Mr J. E. Barnard, nominated by the Royal Microscopical Society.

Sir Ernest Rutherford and Sir Richard Glazebrook were elected Honorary Fellows of the Institute.

The President, in moving the adoption of the Report of the Board for the year 1927, referred to the substantial additions to the membership of the Institute during the year, and to

the increased activities which coincided with the transfer of the offices to South Kensington. The Royal Meteorological Society had been added to the list of participating societies. The arrangement entered into between the Institute and two of the participating societies, the Physical and Optical Societies, had progressed a stage further, and 1 Lowther Gardens had now become the registered office of these two societies as well as of the Institute. A large part of the secretarial and routine work of these societies was now carried out by the staff of the Institute, and the duties included the organization of the Annual Exhibition of the Physical and Optical Societies, for which purpose a Joint Exhibition Committee of the societies had been set up, to which the Secretary of the Institute acted as secretary.

During the year the Institute had received a legacy of £250 from the late Professor A. W. Scott, of St David's College, Lampeter, a Founder Fellow.

JOURNAL OF SCIENTIFIC INSTRUMENTS

An important announcement in relation to the *Journal of Scientific Instruments*, of interest to present and future members of the Institute, was made at the meeting, namely the decision of the Board that, commencing in January 1929, the *Journal* is to be distributed without charge to Fellows, and at a small charge to Associates.

A change in the Editorship of the *Journal* was also announced. Largely owing to ill-health, the resignation of Dr C. V. Drysdale had been tendered and accepted with great regret. The Secretary of the Institute, Mr Thomas Martin, had been appointed Editor, while Dr Drysdale's connection with the *Journal* would be continued by his appointment to act as Honorary Adviser.

PRESIDENTIAL ADDRESS

At the close of the Annual Meeting Sir Frank Dyson gave his Presidential Address, taking as his subject "Physics in Astronomy."

The President described the part Physics had played in the development of Astronomy and Astrophysics. He referred to the successive improvements in the construction of clocks which had led to accurate timekeeping. The lengthening of the pendulum with temperature was met by Graham by employing a cylinder of mercury as the bob, the upward expansion of the mercury balancing the downward extension of the iron or steel rod. In 1726 Harrison made his gridiron pendulum of brass and iron, and this was followed in due course by successive improvements in the compensating pendulum. With Guillaume's discovery of Invar pendulum construction was further improved and simplified.

For the maintenance of the pendulum, Hooke's anchor escapement enabled the clock time to be controlled by a pendulum swinging in a small instead of a large arc, and Graham's dead-beat escapement was a further great improvement. The independence of the "judiciary" and the "executive," *i.e.* of the pendulum and the clock train, was largely secured by Riefler's work. The latest solution of the difficulties, resulting in a nearly perfect time-keeper, has been made by Mr Shortt in conjunction with Mr Hope Jones of the Synchronome Company, in the clock they have produced.

Sir Frank Dyson then referred to the work of astronomers in ensuring uniformity of timekeeping by the distribution of time signals. Beginning with the Time-ball which was dropped by hand, and which was instituted by Pond at Greenwich at the commencement of the last century, he traced the development of the distribution of time signals, which was aided by the electric telegraph, to the final stage in which wireless is used in the co-operation of Greenwich with the British Broadcasting Station.

Increase in the size of telescopes had called for the assistance of the engineer and physicist in the provision in the observatory of driving clocks and electric motors for moving the instruments and turning the domes and shutters; while the manufacturers of optical glass had provided one of the principal and most important fields for the practice of physics in the service of the astronomer. The production of object glasses of increasing size had led to the observations of double stars at Lick and elsewhere, to the determination of the radial velocities of stars by Campbell and his associates, and to the measurements of stellar parallax.

In recent years the applications of the spectroscope by astronomers had resulted in the growth of a new science of astrophysics, the observations of Huggins leading in the hands of Lockyer, Fowler and others to the highly important laboratory work on the differences between arc and spark spectra and their relation, for example, to the eclipse observations of the spectra of the chromosphere. Another direction in which physics and astronomy had advanced together had been in the observation of sunspots and their connection with magnetic storms on the earth, and in the determination of the magnetic fields of sunspots by means of the Zeeman effect.

Sir Frank described also the work on the measurement of solar radiation, which provides a field of equal interest for the physicist, the astronomer and the meteorologist. While the meteorologist delights in rain and clouds they are an unmitigated nuisance to the astronomer, and the difficulties in the determination of the solar constant due to absorption by the earth's atmosphere had called forth the best efforts of the physicist. Finally the application of mathematical physics to astronomy by Einstein was referred to, and the revolution in certain branches resulting from the implications of modern atomic theory, as represented in the work of Eddington and Jeans.

OPTICAL SOCIETY

THE THOMAS YOUNG ORATION was given before the Optical Society on May 16th, 1928, by Professor G. W. Ritchey, who took as his subject "The Modern Reflecting Telescope." Professor Ritchey described his experiences in the construction and use of the great telescopes of Yerkes and Mount Wilson Observatories, including the figuring of the 60-inch and 100-inch mirrors—the former weighing about 1 ton and made from one melting is a perfect disk, but the latter weighing about 5 tons made from 3 successive melts is full of minute bubbles. The lecturer exhibited a number of lantern slides, illustrating the construction of the different forms of reflecting telescopes, including the compact Ritchey-Chrétien type, and showed some of the magnificent photographs of spiral nebulae and star clusters obtained by Professor Ritchey himself with the 60-inch instrument.

The account given of the new cellular mirrors was of great interest. In these weight is economized and construction simplified by building up the glass disk carrying the reflecting surface in sectors, which are fitted together and cemented before polishing. This composite disk, which is comparatively thin, is carried on an arrangement of glass ribs, forming a cellular structure, which separates it from a parallel supporting disk similarly built up in sectors. The whole composite structure provides a rigid mirror of about a quarter the weight of the comparable solid disk.

Professor Ritchey also described the construction of his fixed universal vertical telescope which permits the various types of telescope described in an earlier part of the lecture to be quickly interchanged, and outlined his plans for the future. He explained that the increased resolution of such a giant instrument, which when completed would be two or

three times larger than any existing telescope, could only be used with full advantage over a patch of the heavens included within about 10° or 12° from the zenith, and he hoped that in the course of time a series of five of these giant instruments would be erected about 20° apart, extending from latitude 40° N. to 40° S.

A series of articles upon the subject of Professor Ritchey's Thomas Young Oration has appeared in *L'Astronomie*, Bulletin de la Société Astronomique de France, commencing with the December number of 1927, and the same series in English is now appearing in the *Journal of the Royal Astronomical Society of Canada*. ALAN POLLARD.

CATALOGUES

VENNER TIME SWITCHES, LTD., 45, Horseferry Road, Westminster, S.W. 1, send their lists nos. 43 and 45 describing various uses of their clock switches. These include, for example, application to late shop window lighting, to the switching on and off of a broadcast receiving set at stated hours, to alarm bell ringing and other purposes. List no. 46 describes the Venner Thermostat, in which the differential expansion of a brass tube and the invar rod operates a mercury switch.

A. GALLENKAMP AND CO., LTD., 19 and 21, Sun Street, Finsbury Square, London, E.C. 2, send new lists nos. 263*a* and 71*e* of chemical balances and weights, and also list no. 101*F* of miscellaneous laboratory apparatus at special rates. They send particulars also of a neat and inexpensive vest pocket microscope, resembling a fountain pen in appearance.

We have received from F. HELLIGE and Co., Freiburg im Breisgau, Germany, a booklet no. 1059*e* describing a new Immersion Colorimeter specially designed for accurate measurement of hydrogen-ion concentration. Their list no. 22*E* Pro. illustrates the Hellige Comparator, already described in this *Journal* (July 1927) and other colorimeters, nephelometers, sphygmomanometers and instruments for physiological and medical use.

A pamphlet has been received from TROST BROTHERS, 104, Victoria Street, London, S.W. 1, describing a new material, Haveg, for use in chemical plant and for other purposes, which is highly resistant to corrosion. It is stated to withstand the action of non-oxidizing acids, both organic and inorganic, and many other corrosive substances. It is described as a phenol-formaldehyde condensation product of the "Bakelite" class, in which an acid-resisting filler, usually asbestos, is used. Its specific gravity is given as 1·6 and its compressive strength 5·2 tons per sq. inch. It can be used up to 130° C. and is impervious to sudden changes of temperature; has a homogeneous structure and can be machined, and is normally a good electrical insulator.

MESSRS W. WATSON and SONS, LTD., 313, High Holborn, W.C. 1, send a new list (May 1928) of second-hand microscopes and accessories, in which are offered a number of instruments by well-known makers, as well as objectives, eyepieces and miscellaneous apparatus.

It will be appropriate to refer here to that interesting little publication, *Watson's Microscope Record*, which is sent free of charge by Messrs W. Watson and Sons to those who desire to receive it, and for which they are at present revising their mailing list. This publication, which is frankly concerned with the interests of British microscopy in general and of those of Messrs W. Watson and Sons in particular, contains much matter of interest for microscopists. Thus the issue for May 1928 contains articles on "Ciliary Movement in Diatoms," by A. A. C. Eliot Merlin; "The Microscope in the Foodstuffs and Confectionery Industries," by T. Macara; "The Use of High Powers," by F. J. Brislee; "The Microscope in the Iron and Steel Industry," by A. W. Reed; "Grain in Photomicrography," by T. Thorne Baker.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V | JULY, 1928 | NO. 7

THE CONTOURING OF SMOOTH SURFACES.

By JAS. P. ANDREWS, M.Sc. East London College.

[*MS. received, 17th April, 1928.*]

ABSTRACT. By the employment of a very narrow intense beam of light, the shapes of smooth surfaces may be investigated. The paper describes appropriate experiments, and gives the necessary calculations for regular spherical and cylindrical lens-surfaces; a complete, nearly circular cylinder; and a metal surface of no prescribed figure. The application to glazed porcelain surfaces is alluded to; and it is shown that an accuracy comparable with that of an interference method is attainable by this method.

THE curvature of a slightly curved, regular surface is commonly found by an interference method, but in the course of research the need is occasionally felt for another simple method of comparable accuracy but wider scope. Two reflection methods at least, described respectively by Kohlrausch* and by Searle†, already exist, both bearing some resemblance in principle to the present method, but differing from it in so far as they are restricted to regular surfaces like those of a spherical lens. The method to be described may be applied to any smooth surface, spherical, cylindrical, irregular; glass, polished metal or glazed porcelain, with almost equally accurate results. The principle was indeed first suggested by Dr A. Ferguson, as a method for investigating the surface of a polished brass plate, and the results mentioned here for such a surface are from work performed in collaboration with him.

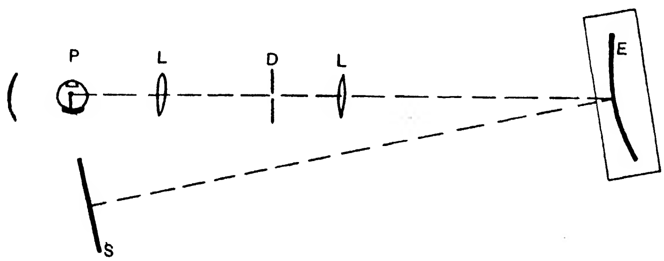


Fig. 1

The essence of the method is the reflection of a very fine, intense pencil of light, approximating to a geometrical ray, from the smooth surface concerned. The reflected pencil produces a small bright spot of light on a distant screen; and the motion of this spot as different portions of the surface are made to reflect the pencil, indicates the shape of the surface. Provided the pencil is narrow enough, even a considerably curved surface will produce on the screen a spot of light of only moderate size (say 1 mm. diameter).

The optical arrangement is shown in Fig. 1, where P is an intense steady source of light—*e.g.* a *Pointolite*—LL are lenses, D is a paper diaphragm pierced by a fine hole, about

* Kohlrausch, *Physical Measurements*. † Searle, *Experimental Optics*.

·02 cm. diameter. E is the surface under investigation, and S the screen, separated by any convenient distance from E and perpendicular to ES. E is set on the base of a travelling microscope, or similar arrangement, capable of moving in a definite direction by measured amounts.

THE ACCURACY OF THE METHOD

Example (1). *Spherical Lens*

The closeness of agreement with a carefully performed interference measurement on the same surface gives an indication of the precision attainable. A spherical spectacle lens of ·25 dioptre power was blacked on the back and mounted at E facing the light. The reflected ray will remain in one plane only if incidence occurs along a great circle of the surface, and this was secured by adjusting the apparatus until the path of the spot at S,

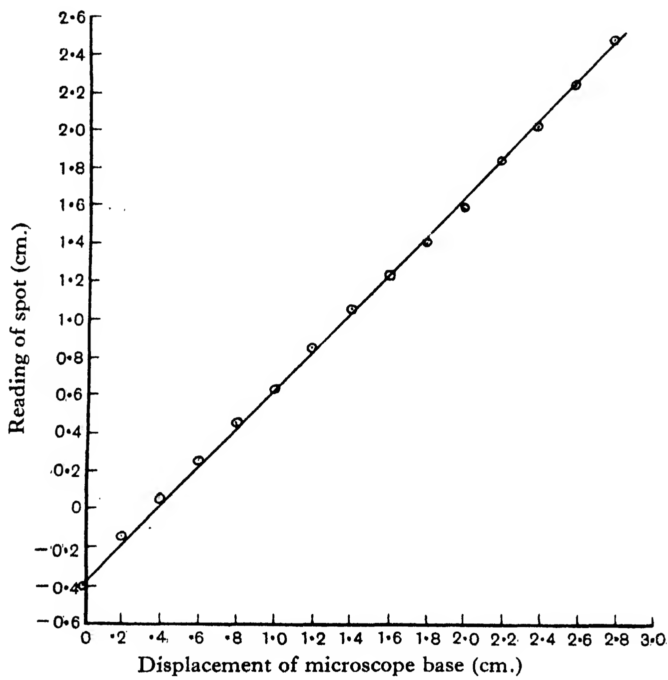


Fig. 2

as the lens was traversed at E, was rectilinear. Moving the lens, now, by equal steps perpendicularly to the normal at its centre, the corresponding positions of the spot were recorded and graphed as in Fig. 2. The travelling microscope was an ordinary laboratory instrument, and a test of possible curvature of its bed was made by substituting an accurately plane surface—the face of a good prism—for the lens. This elicited the fact that the microscope moved in an approximately circular path of radius 3680 cm. in the opposite sense to that of the lens-surface. With this information, and given that $ES = 225{\cdot}3$ cm., the radius of curvature, as calculated from the slope of the graph, was 402 cm.

By Newton's Rings R was found to be 403 cm.

Example (2). *Cylindrical Lens*

For a cylindrical surface, such as that of a cylindrical lens, a very similar procedure is adopted. The axis of the cylindrical lens-surface is first adjusted to be parallel to the

direction of its motion, by turning the lens until the path of the spot is rectilinear. In an actual example the radius of curvature R was found to be, by the present method, 105·7 cm. R by interference method was found to be 105·2 cm.

Example (3). *A Complete Cylindrical Surface*

By a slight modification we may find accurately to what extent the section of a cylindrical surface departs from the truly circular. Thus, an ostensibly circular glass cover, the radius of whose cross section was about 7·70 cm., was placed upon a spectrometer table and adjusted by eye to be roughly coaxial with the table, and in such a position that the incident pencil was directed to a point on the axis. The motion of the spot when the spectrometer table rotated was due to three causes, viz.:

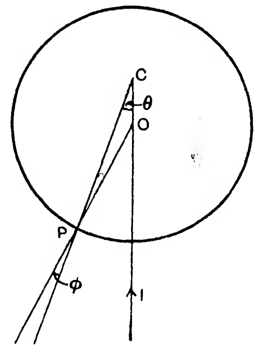


Fig. 3

(1) *Irregularity in the rotation of the spectrometer.* The spectrometer may be rotated through 180° relative to the table and the readings repeated. The means of the two sets will be practically free from this error.

(2) *The eccentricity of the cylinder with respect to the axis of rotation.* Any simple device for centering the cylinder on the table will eliminate this, but otherwise correction is easy. Let C, Fig. 3, be the centre of rotation, O the approximate centre of the cylinder. Then if $OC = h$, $OP = R$, $\dfrac{\sin\phi}{\sin\theta} = \dfrac{h}{R}$. If IOC is the direction of the incident beam for zero rotation of the spectrometer, then ϕ is the angle of incidence when the spectrometer is turned through θ. The distance h, and therefore ϕ, is always small. Hence $\phi = \dfrac{h}{R}\sin\theta = \dfrac{x}{2D}$, where x is the horizontal displacement of the spot relative to the zero position, and D = distance from surface to screen. From the observed positions of the spot, and the corresponding readings of the spectrometer, the zeros of x and θ are readily found. Next, x is plotted against $\sin\theta$, and the best straight line through the origin is drawn. Its slope determines $\dfrac{2Dh}{R}$. Then the effect of eccentricity may be eliminated by subtracting, from each value of x, the corresponding value of $\dfrac{2Dh}{R}\sin\theta$.

(3) *Irregularities in the surface of the cylinder.* The corrected displacements

$$X = x - \frac{2Dh}{R}\sin\theta,$$

are those which would be obtained if the axis of the cylinder were the true axis of rotation. Take the origin of polar coordinates r, θ on this axis, and let the line $\theta = 0$ be the initial line. Let PT be the tangent at any point P on the surface, OP the radius vector, and the angle between PT and OP produced be ψ. Then $\cot\psi = \dfrac{1}{r}\dfrac{dr}{d\theta}$. If the cylinder were truly circular, ψ would be equal to $\dfrac{\pi}{2}$. Suppose actually $\psi = \dfrac{\pi}{2} + \omega$, then $\cot\psi = -\tan\omega$; and since ω is always small,

$$\omega = \frac{1}{r}\frac{dr}{d\theta} = \frac{X}{2D} \text{ approximately.}$$

On integrating, since by definition $\omega = 0$, $r = r_0$ when $\theta = 0$,

$$\log_e \frac{r}{r_0} = \frac{1}{2D}\int_0^\theta X\,d\theta.$$

Or, nearly enough, since r differs only slightly from R, the average value of r, $\omega = \frac{1}{R}\frac{dr}{d\theta}$ approximately, and integrating, $r = R\left(1 + \frac{1}{2D}\int_0^\theta X\,d\theta\right)$ to the same approximation. X is plotted against θ, as in Fig. 4, and the integration performed by planimetry or otherwise, a simple operation.

Example: $R = 7{\cdot}70$ cm., $D = 150$ cm.

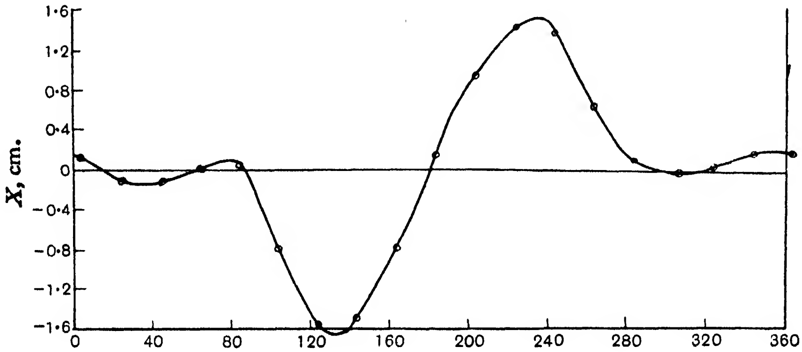


Fig. 4

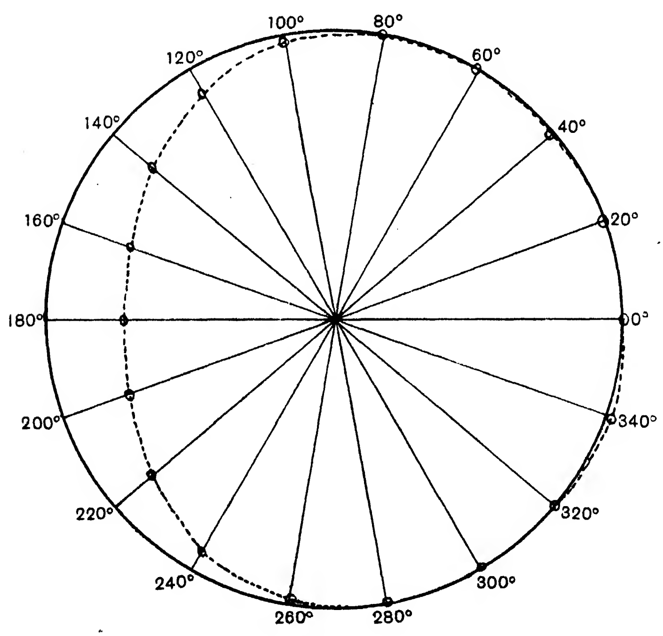


Fig. 5

Upon plotting x against $\sin\theta$, $\frac{2Dh}{R}$ was found to be $8{\cdot}0$. The distance h is therefore about $0{\cdot}205$ cm. The values of x were now corrected, and the integration performed. The final result is presented in Fig. 5, where the deviations from the exact circle are magnified ten times (dotted line). The following list, however, gives a better idea of the sensi-

tiveness of the method, small deviations impossible to represent on the diagram being readily shown:

θ	Correction $\frac{R}{2D}\int X\,d\theta$
0°	0 cm.
80	$-4{\cdot}2\times 10^{-3}$ cm.
160	$-187{\cdot}7\times 10^{-3}$ cm.
240	$-75{\cdot}9\times 10^{-3}$ cm.
320	$-5{\cdot}7\times 10^{-3}$ cm.

Example (4). *A Metal Surface*

We are not restricted to glass surfaces, a polished metal face being a sufficiently good reflector. In point of fact, brass bars, bent by couples at their ends, have been extensively investigated by this method. All that remains to describe is the method of computation, the experiment being performed as in the case of the lens, example (1). Let IN (Fig. 6)

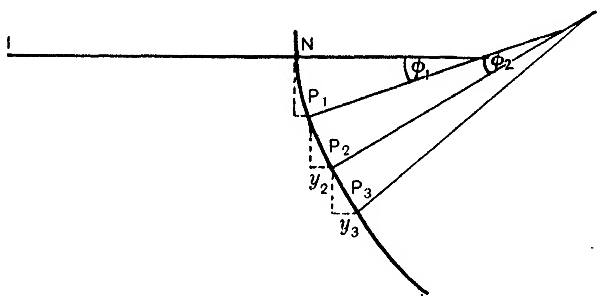


Fig. 6

be the normal to the surface at N, where the light is first incident; let $NP_1 = P_1P_2 = P_2P_3$, etc. $= d$ cm., the distance by which the surface is moved each time; and let ϕ_1, ϕ_2, etc., be the angles between consecutive normals at N, P_1, P_2, etc. If y is the depression of the surface below the tangent at N, y_n the contribution to y in the interval $P_{n-1}\,P_n$, it appears immediately that

$$y_n = y_{n-1} + d\tan\left(\phi_{n-1} + \frac{\phi_n}{2}\right)$$

very nearly, and as $\tan 2\phi = \frac{x'}{2D}$, or approximately $\phi = \frac{x'}{4D}$,

$$y_n = y_{n-1} + \frac{d}{4D}\left(x'_{n-1} + \frac{x_n'}{2}\right),$$

where x' is the additional displacement of the spot when the point of incidence moves from P_{n-1} to P_n. This gives

$$y_n = \frac{d}{4D}\left(x_1' + x_2' + \text{etc.} + \frac{x_n'}{2}\right),$$

as the formula from which the shape of the surface may be calculated.

Finally, the surface of a flat glazed porcelain tile was investigated by this method. It was found that the reflection was quite intense enough to enable measurements to be taken, from which the contours of the surface could easily be calculated. Nothing new arises in this case, however, and the mention of a successful trial is sufficient.

A NULL METHOD FOR DETERMINING MAGNETIC FIELD INTENSITY.

By C. T. LANE, M.Sc. Macdonald Physics Laboratory, McGill University.

[*MS. received, 8th March, 1928.*]

ABSTRACT. A null method is described for the accurate measurement of a magnetic field in terms of the field inside a standard solenoid coil. This gives an improvement in both speed and accuracy over existing methods.

I. Introduction

Of all the methods available for determining magnetic field intensity the use of the ballistic galvanometer in conjunction with some form of exploring coil seems to be the most reliable. However, due, in part, to the necessity of galvanometer readings being taken both in calibrating the instrument and in actual determinations with the search coil, the method admits of considerable error. The following method has accordingly been devised in which direct readings of the galvanometer become unnecessary for an absolute determination of magnetic field strength.

II. Theory

Suppose a search coil of n turns and mean cross sectional area A be placed with its plane perpendicular to the lines of force (H_0) and rotated through 180° about an axis in its own plane. The quantity of electricity which will flow through a circuit connected to the coil will be

$$Q=\int_0^T i\,dt=\frac{1}{R}\int_0^\pi \frac{d}{dt}(H_0An\cos\phi)\,dt-\frac{1}{R}\int_0^0 L\,di=\frac{2H_0An}{R} \qquad \text{......(1)},$$

where R is the total resistance and L the inductance of the circuit of which the coil forms a part.

Again, if a current I be reversed in the primary of a mutual inductance M, the charge flowing in a circuit connected to the secondary, again of resistance and inductance R and L respectively, will be

$$Q_1=\int_0^T i\,dt=\frac{1}{R}\int_{-I}^{I} \frac{d}{dt}(Mi)\,dt-\frac{1}{R}\int_0^0 L\,di=\frac{2MI}{R} \qquad \text{......(2)}.$$

If now the search coil and the secondary of a mutual inductance be connected in series with a ballistic galvanometer forming a circuit of resistance R_1, and both the operations expressed by (1) and (2) respectively be performed simultaneously, then we shall have, for no resultant galvanometer deflection,

$$\left.\begin{aligned} Q&=Q_1\\ \textit{i.e.}\qquad H_0&=\frac{MI_0}{nA}\end{aligned}\right\} \qquad \text{......(3)},$$

where I_0 is the value of the current necessary to produce no deflection of the galvanometer.

III. Experimental Arrangement

From what has been said it will be evident that some scheme must be provided whereby the current in the primary of the mutual inductance will be reversed while the search coil is actually cutting the lines of force. In the accompanying Fig. 1 is shown the apparatus in which this condition is realized. The search coil is shown at C suitably mounted on a shaft which is provided with a small handle H, fitted with stops, such that it may be rotated through 180°. The shaft is operated by means of a fairly stiff spring T. Flexible leads L are taken from the turns of the search coil to the galvanometer circuit. Mounted on the same shaft which carries the search coil is a split ring commutator N consisting of two separate brass rings mounted on an ebonite disc. Upon each ring runs a sliding phosphor bronze

contact indicated in the figure at *EE*. Binding screws numbered 3 and 4 are connected to each of the brass segments respectively by means of flexible leads (not shown in the figure). Binding screws numbered 1 and 2 are connected to *EE* as shown. In turning through 180° it can be easily seen that this commutator acts as a reversing switch.

In using the instrument (Fig. 2) current is supplied from a storage cell *E* via terminals 3 and 4 through the primary of a mutual inductance *M* (about $\frac{1}{2}$–1 millihenry) connected to terminals 1 and 2. The galvanometer circuit includes the search coil, the secondary of the mutual inductance and, if necessary, additional resistance *R*, all in series with the galvanometer *G*. Matters are so arranged that, acting separately, the search coil and mutual inductance secondary produce deflections in opposite directions.

The current is then adjusted until a balance is obtained when both act together, whence the field is given by equation (3).

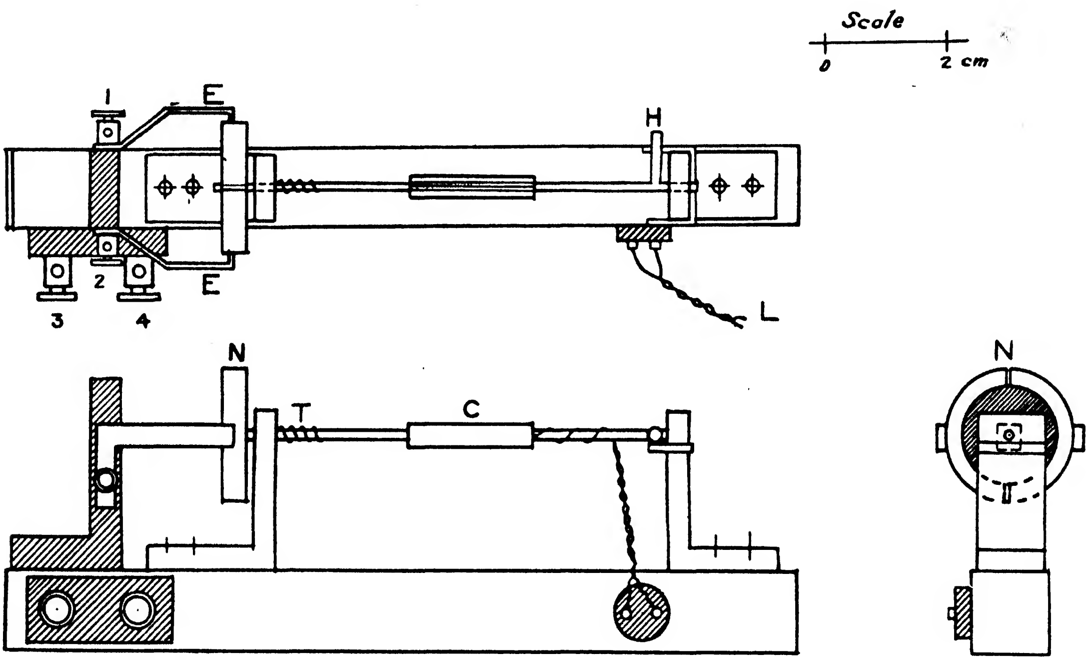


Fig. 1

In the instrument used by the writer almost perfect balance was obtained. It should be noted in this connection that the ratio of the time of motion of the coil to the free period of the galvanometer should be as small as possible. To bring this about not only should a long period galvanometer be employed but also the moving parts of the search coil should be as light as is consistent with mechanical strength.

In the instrument described here the search coil was of rectangular section 2 cm. × 0·3 cm. with 4 turns of wire. The outside diameter of the commutator was approximately 2 cm. The construction was of brass with the exception of the insulating supports—shown shaded in Fig. 1—which were of ebonite. The sliding contacts *EE* were of phosphor bronze as was also the spring *T*. The instrument is drawn to roughly full size in Fig. 1.

The accuracy with which the constant M/nA can be determined depends a good deal on the care with which the search coil is made, since *M* can be calculated to a high degree of accuracy. This constant is especially liable to error where very small search coils must be used, as, for instance, in the survey of a field which varies rapidly from point to point. The constants of such a search coil may be determined in terms of a larger one, the constant of

which can be accurately calculated, by placing both in turn in a uniform field and obtaining balance currents for each. The constant of the small coil would then be determinable in terms of the constant of the larger one and the ratio of current values. The degree of uniformity of the field could be checked by comparative measurements with the smaller coil.

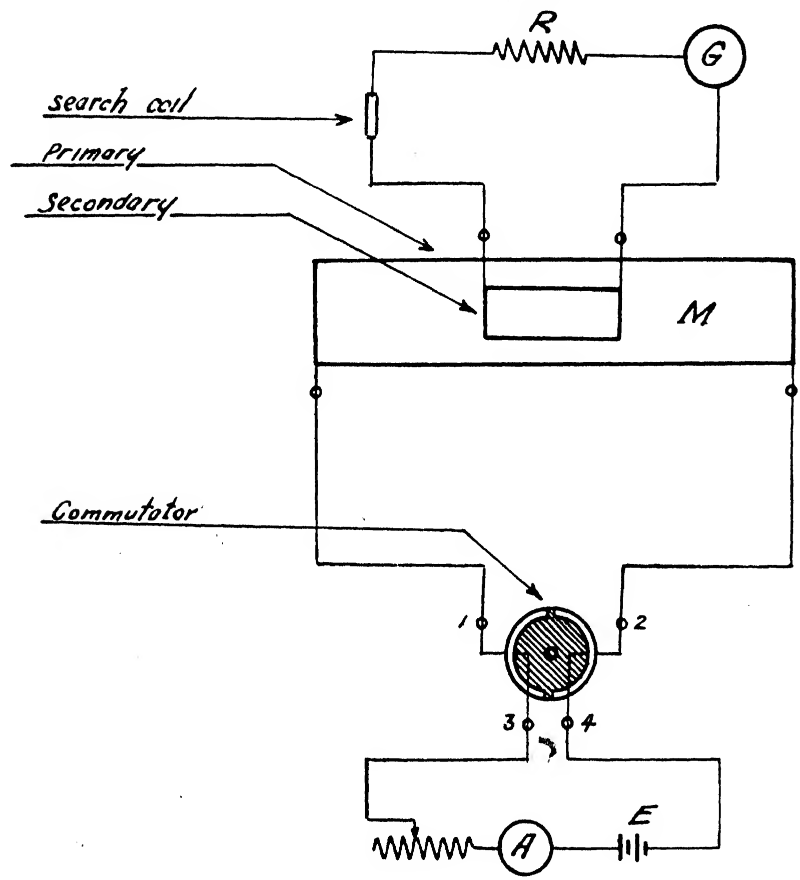


Fig. 2

IV. Conclusions

The device appears to have the following advantages over the older method:

(1) Direct galvanometer readings are eliminated, thereby avoiding, to a considerable degree, the corresponding experimental error.

(2) No restriction is placed, within wide limits, on the amount of resistance which may be employed in the galvanometer circuit.

(3) Errors due to possible changes in the galvanometer constant or in the resistance of the galvanometer circuit in the interval between calibrating and making direct observations (in the older method) are avoided; also such errors as might arise through the galvanometer not returning to its initial position after a deflection.

(4) Where a large number of observations have to be made the amount of labour involved is considerably lessened.

In conclusion the writer desires to express his thanks to Dr E. S. Bieler of the Department of Physics for the suggestions he has made in connection with this work. He is also indebted to the National Research Council of Canada for a Bursary during the tenure of which this work was done.

A DEVICE FOR CONTROLLING THE RATE OF COOLING AND HEATING OF THE HAUGHTON-HANSON THERMOSTAT.

By J. D. GROGAN, B.A. Metallurgy Department, The National Physical Laboratory.

[*MS. received*, 30*th January*, 1928.]

ABSTRACT. The Haughton-Hanson thermostat consists of a silica bulb in an electric resistance furnace and attached to a mercury relay. Expansion of air in the bulb breaks the mercury relay, which in turn breaks or lowers the current heating the furnace. The device here described consists of an electrolytic cell which delivers oxygen to the thermostat bulb at a steady rate and produces a steady fall of temperature in the bulb. By diverting the gas to a counterpoise bulb attached to the other side of the mercury relay the temperature of the thermostat may be made to rise steadily.

Introduction

In the Haughton-Hanson thermostat* temperature is controlled by the contraction and expansion of air in a silica bulb enclosed in an electric furnace. The air controls a mercury relay which in turn controls a main relay carrying the heating current of the furnace. The arrangement is shown diagrammatically in Fig. 1. *A* is the thermostat bulb, *B* a compensating bulb, and *C* the mercury contact. The current flowing in the furnace heats bulb *A* and causes the gas in it to expand and break the mercury relay contact. This causes the main relay to reduce the heating current. The bulb cools and in time the mercury relay closes again. Thus the gas in the bulb is regularly heated and cooled through a small temperature range.

If the mass of gas in the bulb is increased the temperature of the furnace will fall further before the mercury contact is again established. By controlling the rate of increase of the mass of gas the rate of cooling of the furnace can be controlled. The electrolytic cell, by providing a steady stream of gas, affords a simple and easily controlled means of achieving this end.

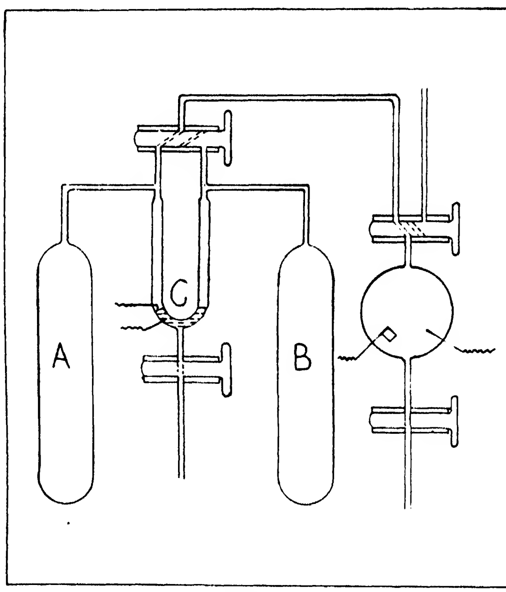


Fig. 1

Electrolytic Cell

This is shown in Fig. 1. It consists of a glass bulb of about 100 c.c. capacity provided with two electrodes, the anode a small platinum wire, the cathode a piece of platinum foil. The bulb is closed at the bottom by a glass tap. By means of a three-way tap at the top the cell is opened to the air or connected to the thermostat system. By another three-way tap connected to both arms of the mercury contact U-tube the cell is made to deliver gas either to bulb *A* or to bulb *B*. To produce slow cooling the cell is connected to bulb *A* and a suitable current is passed through the cell.

* *J. Inst. Met.* **14** (1915) 145, and **18** (1917) 173.

Let V be the volume of bulb A.
T be the absolute temperature of bulb A.
v be the volume of gas at N.T.P. generated by unit current in the electrolytic cell in unit time.
c be the current in the cell.

In t units of time the volume of gas generated by the cell is tvc, assuming that the pressure is normal. As the system is working substantially at constant pressure and volume all this gas passes into bulb A, the temperature of which has fallen to T_1 absolute. The volume of this gas, therefore, becomes $\frac{T_1}{273}\, tvc$. The gas originally in A has cooled from T to T' and has changed in volume from V to $\frac{T_1}{T}\, V$.

If the change in volume of the silica bulb is ignored,

$$V = \frac{T_1}{T} V + \frac{T_1}{273}\, tvc,$$

$$\frac{T - T_1}{t} = \frac{vc}{273}\, TT_1.$$

The rate of cooling for a given set of conditions is given by

$$\frac{dT}{dt} = CT_1 (T_1 + dt)$$
$$= CT_1^2,$$

and is, therefore, proportional to the square of the absolute temperature.

To produce slow heating the cell is connected to bulb B which is working at constant temperature. The electrolytic gas raises the pressure in B. The pressure in A rises equally, the increase in absolute temperature being proportional to the increase in pressure. When slow heating is in progress the thermostat works under constantly increasing pressure. To avoid leakage it is necessary to restore the pressure to normal occasionally. The heating will then continue as before, but at an increased rate owing to the change in initial absolute temperature.

Choice of Electrolyte

If sulphuric acid is used as electrolyte an explosive mixture of oxygen and hydrogen is generated, an undesirable material to introduce into the thermostat. It is, therefore, necessary to prevent the evolution of hydrogen. This may be done by using as electrolyte the solution of a metallic salt as copper sulphate, or of an oxidizing agent such as chromic acid in sulphuric acid. The solution used should have a low vapour pressure in order to avoid as far as possible the introduction of water vapour into the thermostat. A 50 per cent. solution of sulphuric acid is satisfactory in this respect, but is a poor solvent for inorganic salts. However, both copper sulphate and chromic acid are sufficiently soluble for employment as electrolyte.

When copper sulphate is electrolyzed, copper is deposited on the cathode. When the current is stopped the copper reacts with the solution and some cuprous sulphate is formed. This reacts with the oxygen evolved when the current is started again and interferes with the operation of the cell. Copper accumulates on the cathode and must be removed periodically. For these reasons chromic acid solution is preferred as electrolyte. It has to be renewed periodically, but otherwise appears to possess no undesirable properties. A saturated solution of chromic acid in equal parts of water and sulphuric acid is used. When this solution is employed it is necessary to grind in the lower tap of the cell carefully.

The gas evolved by this solution attacks rubber rapidly. Joints should, therefore, be sealed and not made with rubber. The gas, although presumably it contains ozone, does not appear to foul the mercury in the relay.

Current Consumption of the Cell

The limit of current that may be employed in the cell is that current which just does not cause liberation of hydrogen at the cathode. In the cell described that limit is 6 milliamperes, which gives a rate of cooling at 600° C. of over 15° C. per hour. No definite lower limit of current has been measured. The cell will work well with currents much less than 1 milliampere. As the system is closed it does not matter whether the oxygen leaves the anode, as it usually does, in a stream of very small bubbles, or in the form of larger bubbles. Current for the cell is derived from 110 volt mains, which also supply the thermostat. A circuit is made of two high resistance lamps and a variable resistance, which is used as a source of variable E.M.F. for the cell. When the circuit is first closed the current in the cell is considerably greater than the steady current which is established later. It is, therefore, convenient to switch on the current some little time before the cell is required. The back E.M.F. of the cell is approximately 1·4 volts.

The thermostat is frequently attached to the mains by leads of appreciable resistance; consequently the voltage on the thermostat terminals depends on the current consumption and varies appreciably when the thermostat switches on and off. This causes the current in the cell to vary. Within limits this is no disadvantage. As cooling progresses the off period lengthens with respect to the on period and the average rate of evolution of gas consequently increases. This reduces the decrease in rate of cooling which follows the reduction in absolute temperature.

The author wishes to thank Dr J. L. Haughton for his interest and advice in this work and for the extended practical trial he has made of the device.

A SIMPLE METHOD OF MEASUREMENT OF CAPACITY AND HIGH RESISTANCE BY MEANS OF A THERMIONIC VALVE. By G. R. TOSHNIWAL, M.Sc. Research Scholar, Allahabad University.

[*MS. received, 13th June*, 1927.]

ABSTRACT. Charging a capacity by means of a suitable battery and discharging it through the grid-filament circuit, provided with a suitable grid leak, it has been found possible to determine the value of a very small capacity, by noting the change in the anode current. By a similar process values of high resistances have also been obtained.

Introduction

The use of the thermionic valve has of late been extended to the measurement of voltage and capacity. Scott-Taggart* and several others, using heterodyne methods, and Karolus and Prince†, Gorbatscheff‡ and Dowling§ using other methods, while not successful in measuring capacities of the order of a few cm., succeeded in measuring small *changes* in capacity. The quadrant electrometer methods used by Mukerjee|| and others are very

* Scott-Taggart. *Electrician*. April 1919.
† Karolus and Prince. *Phys. Zeits.* **22** (1921) 362.
‡ K. Gorbatscheff. *Phys. Zeits.* **25** (1924) 485.
§ J. J. Dowling. *Roy. Dub. Soc. Proc.* **16** (1920) 175.
|| A. T. Mukerjee. *Phil. Mag.* **38** (1919).

elaborate and inconvenient, though the bridge method recently developed by Hartshorn* may be quite handy. Dowling† made use of the cumulative grid rectification property of the valve and found that the relation between capacity and galvanometer deflection was linear, but he was obliged to use metallic screening to avoid unsteadiness of the galvanometer. The method now to be described dispenses altogether with screening, and with necessary precautions and a suitable galvanometer is capable of measuring capacities as low as 5 cm. within 1 per cent.

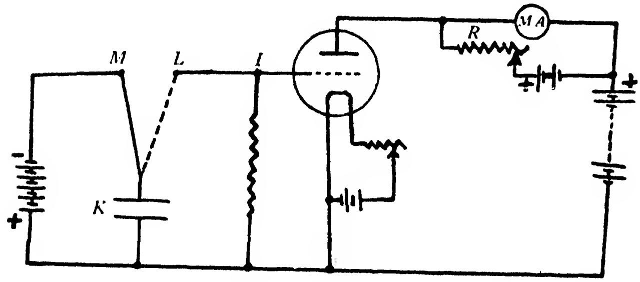


Fig. 1

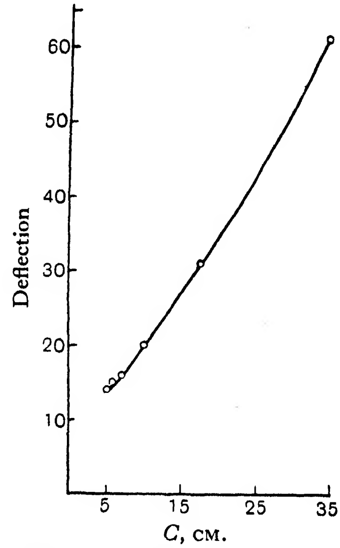


Fig. 2. Charging volts $V = 20$. Grid leak $R = \infty$

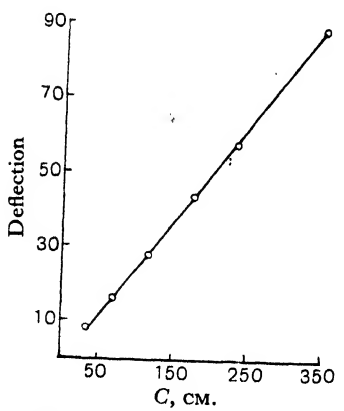


Fig. 3. $V = 10{\cdot}2$. $R =$ pencil line

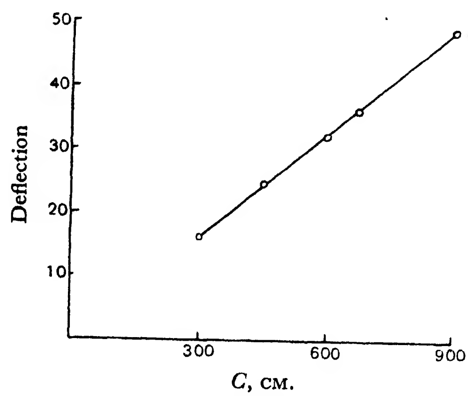


Fig. 4. $V = 10{\cdot}2$. $R = 6\Omega$

EXPERIMENTAL ARRANGEMENT

The arrangement used is shown schematically in Fig. 1.

The figure is self-explanatory. K is a condenser which is charged as shown by the battery on the extreme left. The initial anode-filament current is balanced by a separate battery and a continuously variable resistance. The balancing resistance R should be much greater than the resistance of the microammeter MA. The anode potential is such that with no grid bias the zero grid line comes to the middle portion of the characteristic curve. K is then

* L. Hartshorn. *Phys. Soc. Proc.* **36** (1924) 399.

† Dowling. *Loc. cit.*

discharged through the grid-filament circuit, by connecting K to L as shown by the dotted line. A suitable value of the grid leak is chosen so that with the capacities to be measured the deflection in MA is not greater than the range of the instrument. With these precautions the deflections for various values of K and grid leak were noted and graphs plotted. See Figs. 2, 3, 4 and 5.

Taking a suitable condenser and varying the grid leak it was found that a linear relation existed between the grid leak resistance and the deflection. This is shown in Fig. 6.

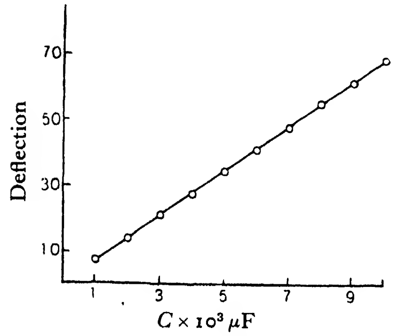


Fig. 5. $V = 10{\cdot}2$. $R = 0{\cdot}6\,\Omega$

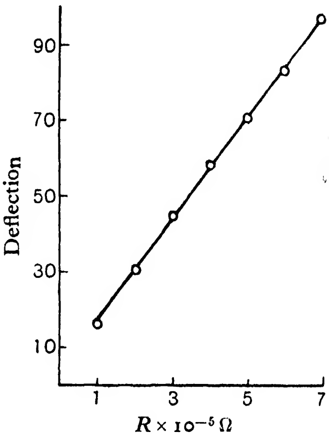


Fig. 6. $V = 10{\cdot}2$. $C = 0{\cdot}048\,\mu F$

Discussion of the Results

Leaving aside the first graph (Fig. 2) for very small capacities, it is evident that a linear relation exists between the capacity and the momentary deflection in the microammeter. When a certain quantity of electricity is discharged through the circuit, due to the capacity effect of the electrodes, the grid is momentarily charged to a certain voltage and we get a corresponding deflection of the microammeter. The voltage thus applied to the grid evidently depends, therefore, upon the quantity of electricity discharged through the grid filament, which in turn depends upon the grid leak. In the anode circuit we are also dealing with a momentary current, *i.e.* a quantity of electricity, and hence it is to be expected that the deflections will be directly proportional to the quantity of electricity discharged, as is the case when a capacity is discharged through a ballistic galvanometer. But the results given here are all those obtained by using the microammeter, and it is certainly more handy and convenient to use.

In the case of Fig. 2, a parallel plate condenser was used, and as it was not provided with a guard ring, the simple formula $C = \dfrac{A}{4\pi d}$ does not rigidly hold, and is likely to introduce some curvature in the relation. This curvature can also be attributed to the fact that the capacity of connecting wires, etc., becomes a considerable factor; but as we continue with higher and higher capacities, this curvature disappears and the relation becomes linear.

In conclusion I wish to thank Professor M. N. Saha and Mr S. R. Bhargava for their kindly help and interest shown throughout the progress of the work.

NON-INDUCTIVE COILS AND RESISTANCE BOXES. By D. C. GALL.

Non-inductive resistance coils of single values such as 1, 10, 100 or 1000 ohms can be wound in several ways to give very small values of residual inductance. Most non-inductive coils have been in their early stages adaptations of standard resistance coils, mostly bifilar wound. With such of these as are used in direct current bridges, etc., it is usually found that coils of below 100 ohms are positively inductive, and above 100 ohms negatively inductive, that is, have a preponderance of capacity. The 100-ohm coils themselves are very often nearly non-inductive, but may vary according to the diameter of the wire used and the bulk of the coil. In addition apparently similar coils may differ considerably.

Several modes of winding have been devised from time to time. Generally the principle has been to subdivide the high resistance coils in groups in series, to reduce the capacity of the coil and so to arrange the low resistance coils that the return conductor lies very close, by winding concentrically or by using a number of conductors in parallel, twisted or flat.

In order to produce non-inductive high resistance coils complicated configurations have been used in some cases. It has been amply verified that coils in which the wire is subjected to sharp kinks and unequal stresses do not retain their ohmic resistance values well. For this reason coils of this type are not desirable if they can be avoided. Even the twisting together of finely insulated wires increases the liability to unsteadiness and breakdown.

There seems to be a practical limit to which the inductance of the lower resistance coils used in ordinary resistance boxes can be reduced. This appears to be of the following order:

0·1	ohm coils	+ 0·01	microhenry
1·0	,,	+ 0·02	,,
10	,,	+ 0·1	,,

This limit is due to having to produce a small robust coil capable of carrying sufficient current for bridge tests and so constructed that its resistance can be adjusted accurately. The mode employed by Messrs H. Tinsley & Co. is to use a very finely subdivided conductor of D.S.C. manganin wires and to wind the conductor evenly upon a bobbin. One set of ends of the manganin wires are connected so that the going and return currents are very closely intermingled. If too fine a wire is used for the strand the self-inductance becomes too large to be cancelled by the mutual inductance between the going and returning conductor, since the space between cannot be reduced below the thickness of the silk coverings.

Above 10 ohms the effect of the capacity of the coil in neutralizing the inductance begins to be felt, so that at 100 ohms use can be made of this to produce a truly neutral coil. In this connection the varnish used to impregnate the coil has considerable influence, especially if the coils are wound upon porcelain or other insulation. Shellac increases the capacity greatly, and a slightly inductive coil may be neutralized by an additional coat of shellac, the change observed being of the order of 0·2 microhenry on a 100-ohm coil and 20 microhenries on a 1000-ohm coil. This method of adjustment cannot be regarded seriously, but serves to explain the variation found in coils wound to similar specification. If paraffin wax is used for impregnation the changes are much less. Its use for this purpose, however, is not generally recommended as it absorbs moisture.

The method of winding used by Messrs H. Tinsley & Co. for 100- and 1000-ohm coils is to use a single D.S.C. manganin conductor of suitable diameter and to wind the bulk of this

so that a slightly capacitive coil is produced. The remainder is then wound in such a way that the requisite amount of inductance is added to the coil. This can be done after the coil has been finally impregnated and stoved. In some cases this adjustment is operated mechanically, so that by turning a screw the final residual effective value of the inductance can be adjusted to zero when the coil is sealed in its case (see Fig. 1). So long as the residual capacity is very small a resistance coil compensated in this way is almost independent of frequency. Fig. 2 shows the equivalent circuit. There seems little doubt that thoroughly dry coils sealed up in airtight cases preserve their resistance values better than those exposed to changes in humidity and other atmospheric conditions. For this reason standard non-inductive coils are hermetically sealed, the case serving as an electrostatic screen.

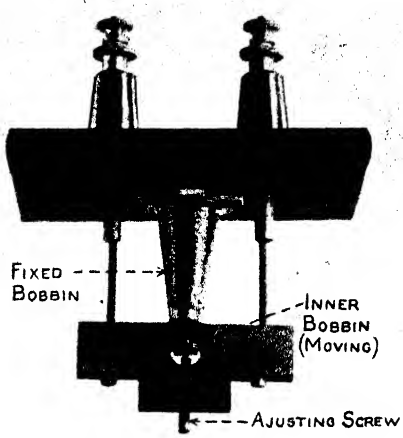


Fig. 1. Non-inductive coil with mechanical adjustment

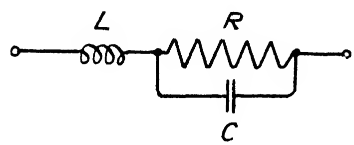


Fig. 2. Equivalent circuit of compensated high resistance coil

From the above it will be seen that the production of a reasonably non-inductive coil is a fairly straightforward matter, and one might almost expect that the non-inductive resistance box would immediately follow. This is not so, however. If ten good non-inductive coils are assembled into the dial of a resistance box the result may be somewhat surprising. The following table shows the result of using ten 1000-ohm coils each having a residual effective inductance of approximately −10 microhenries.

Dial position number	Nominal resistance ohms	Effective inductance microhenries
0	0	+ 1
1	1,000	− 10
2	2,000	− 50
3	3,000	− 110
4	4,000	− 240
5	5,000	− 370
6	6,000	− 500
7	7,000	− 700
8	8,000	− 880
9	9,000	− 1100
10	10,000	− 1250

Fig. 3 illustrates the curve upon which the residual inductance of the box rises for each position of the switch on this 1000-ohm dial. This is taken from an actual box, and it will be seen that the total is over 100 times the individual coil. This curve will vary with the configuration of coil grouping and the distribution of capacity, and may therefore be affected

by the position of the switches of other dials in the box, which suggests the advisability of screening each dial at least.

It will be clear that in order to counteract the almost parabolic rise in negative inductance of this dial the coils must be adjusted according to their position in the dial. This is done in the non-inductive resistance boxes made by Messrs H. Tinsley & Co. The type of winding referred to above is used, and each coil is adjusted to a residual value which will just compensate for the progressive building up of the capacity effect according to the position in the dial. By standardizing the layout of the coils in the boxes definite values can be fixed for the residual inductance to which each coil must be adjusted.

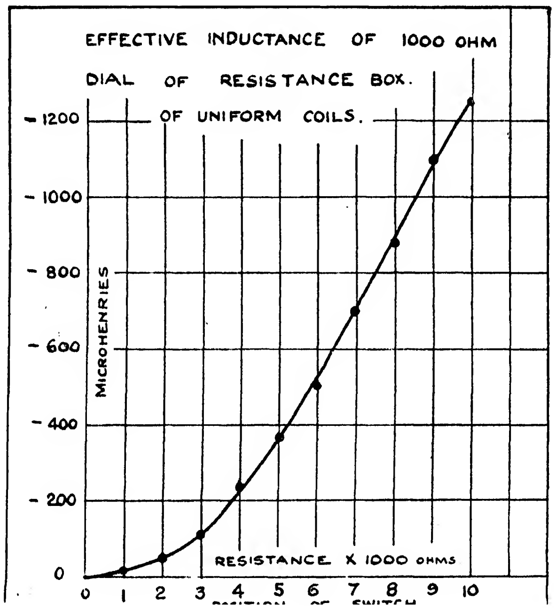


Fig. 3

In the case of the 100-ohm dial it is found that if $L = 2N - 6$ microhenries, when N is the position number of the coil, almost perfect compensation is obtained in the standard box. (L is the effective inductance of the coil at position N.) The compensation of the 1000-ohm dial is more definitely parabolic, as indicated by Fig. 3.

No compensation is found necessary below 100 ohms. The desirability of shielding each coil has been considered, and for special purposes boxes have been constructed in which the screen of each coil is connected to one end of the dial. By this means compensation can be obtained by making

$$L \propto \frac{N-1}{N}\left(1 + \tfrac{1}{2} + \tfrac{1}{3} + \tfrac{1}{4} \cdots \frac{1}{N}\right).$$

Results have not justified the general use of this method. All non-inductive boxes are provided with electrostatic screens, and where every coil is separately screened the increase of capacity to screen is very marked. This is a disadvantage. The double screened boxes are not generally used, but have special applications, no doubt. In any case the method of grading the inductance of the dials overcomes the capacity effects, under specific conditions.

The switches of the box are covered by a bakelite cover lined with metal, which is connected to the metal lining of the box, thus completely screening the resistance unit. Generally the box is adjusted to be non-inductive when the screen is connected to one terminal

of the resistance box. To ensure that the correct terminal is used these are specially marked E and L. The terminal E should be connected to the screen. Network screens are sometimes employed to reduce the capacity to the screen.

In connection with non-inductive boxes the case of the slide wire is worth notice. The return conductor of a slide wire is often doubled back to make it non-inductive. Quite frequently this has increased the inductance between the end terminals of the slide wire. For example, an 18 cm. diameter slide wire of 0·3 mm. diameter wire will have an inductance of 0·75 microhenry for the single turn. A return conductor of similar size will have the same inductance. The inductance will be less for a larger return conductor. If the return conductors are laid side by side, with centres 5 mm. apart, the mutual inductance between them will be 0·33 microhenry. The two together will have an inductance of

$$2\,(L - M) = 0{\cdot}8 \text{ microhenry},$$

thus increasing the inductance. Unless the return conductor is very close, doubling back of internal connections has been found to increase the inductance of the leads, for the same reason.

NEW INSTRUMENTS

A NEW MICROSCOPE

Recently, the question of providing suitable microscopes for general use for research at the new London School of Hygiene and Tropical Medicine in London was under discussion. Whereas the optical properties of microscopes have been steadily improved,

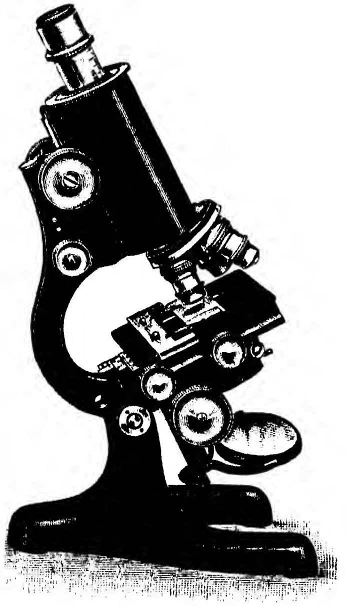


Fig. 1

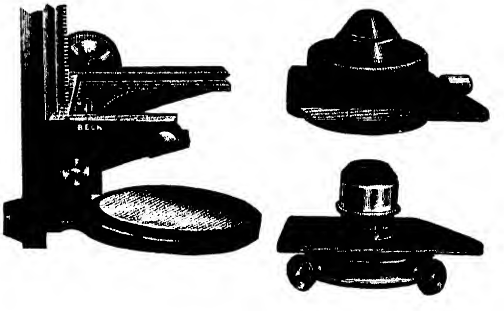


Fig. 2

it was considered that in many respects the design of the stands had become stereotyped and that several features were capable of considerable improvement. The Beck "Pathological" microscope (Fig. 1) was consequently designed by Messrs R. and J. Beck, Ltd., and after several months' trial was adopted for the equipment of these laboratories.

The almost universal plan of carrying condensers and substage apparatus in a cylindrical fitting has been discarded. The process of taking the condenser out of a cylindrical fitting and pushing in the dark ground illuminator is found to be unsatisfactory in practice. The new method consists of mounting the substage apparatus in fittings which slide into a horizontal loose dovetail, with a clamp screw to hold them firmly when in position. This method (illustrated in Fig. 2) was suggested by Mr Akehurst, and provides a means of rapidly changing from transparent to dark ground illumination without affecting the adjustments of the instrument. The focussing of the substage is by means of rack and pinion.

In a model in which the Pathological microscope is also made, the front part of the stage is cut away, as illustrated in Fig. 3. By this means the substage apparatus can be withdrawn from the instrument without any movement of the substage, so that a condenser and a dark ground illuminator can be interchanged with practically no disturbance to the adjustments of the instrument.

The mechanical stage is an integral portion of the microscope, and the object slide is not moved over the surface of a plain stage, but the whole top plate of the stage moves in both

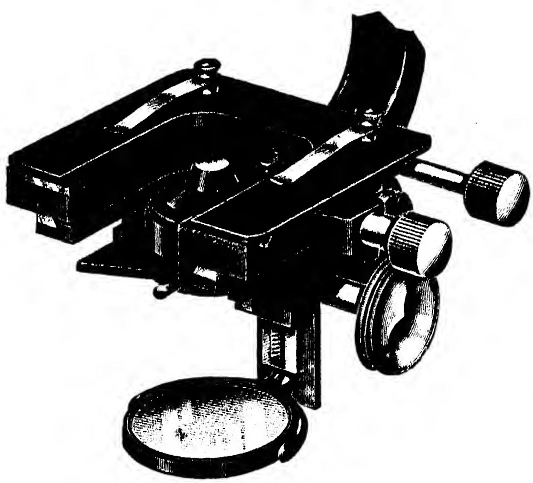


Fig. 3

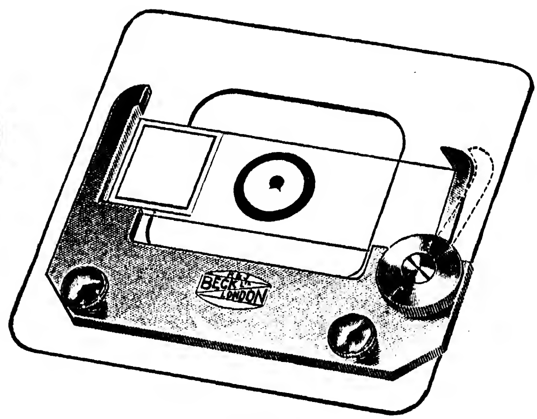


Fig. 4

directions, its surface being flat for the reception of large culture plates, petri dishes, etc. A detachable top stage is attached to the flat plate for holding 3″ × 1″ slips firmly. This was designed for Professor Topley, and consists of a plate, as shown in Fig. 4, with a fixed projection at one end and a clamping arm operated by a revolving milled head at the other. The lateral movement of the stage is operated by a differential screw which gives a very smooth movement, and the vertical movement by a helical rack and pinion of a finer pitch than usually supplied. The milled heads are below the surface of the top stage plate, so as to clear any large plates that may be employed. These milled heads, and also that of the focussing substage, are placed on the left-hand side so that there are no obstructions when the instrument is used for drawing. (Fig. 1 shows them on the wrong side for the convenience of the illustration.)

The body is of the large 2 inch diameter, and has a sliding graduated draw-tube.

The coarse and fine focussing adjustments have received special attention. They have milled heads on both sides, and all the slides are made with large floating surfaces which are in contact all over and are not dependent for their fit on setting up screws or spring fittings. This ensures stability and a wearing quality that has proved in practice far more durable than any other system. All the milled heads of the instrument operate the

adjustments in the same direction, so that the liability of damage to the specimens and the lenses is reduced. The base of the instrument is of a very solid pattern with a large spread. The limb is of a convenient shape for lifting by the hand without putting any strain on the fine adjustment, and the mirrors, which are flat and concave, have the usual adjustments.

The object glasses usually supplied are the 2/3″, 1/6″ and 1/12″, and each power is enamelled in a distinctive colour so that, when used on a revolving nosepiece, they can be easily recognized.

In the past, large and complicated instruments have been made for those who require to use microscopes for a number of different purposes, and small simple instruments have been employed by the student. Sufficient attention has not always been paid to the design of a compact efficient research instrument. This instrument appears to be adequate for the research worker, and not too elaborate for the advanced student.

THE ROTAMETER. SOME LABORATORY APPLICATIONS

THE ROTAMETER (Trost Brothers, 104, Victoria Street, London, S.W. 1) is an instrument designed for the purpose of giving a reliable and accurate indication of the rate of flow of a fluid (liquid or gas). The instrument is shown diagrammatically in Fig. 1 and consists essentially of two parts; a transparent tapered tube and a non-buoyant "float." The flow of fluid passes vertically upwards through the tube, and the float takes up a definite position in which the annular space around it is sufficient to allow the momentary flow to pass with a fixed pressure drop, determined by the weight of the float and its dimensions relative to those of the tube. The float is made to rotate by means of nicks cut in its upper edge, so that it never touches the walls of the tube. There is therefore no wear and the accuracy of the readings remains constant however long the instrument is in use.

Instruments of this type are made in a very large variety of sizes. In the case of small laboratory instruments, with which we are principally concerned in the present article, it is possible to make instruments for flows as low as 100 c.c. per hour.

The accuracy of the Rotameter is a question of some importance. The calibration is done by direct means and with the greatest possible care. A guarantee of $\pm$ 2 per cent. is always given throughout the scale range, but greater accuracy can be provided if required. It should be pointed out that the measurement of a gas flow within 2 per cent. requires quite elaborate precautions. Strict control of temperature, pressure, moisture content and composition of the gas is necessary, and it is quite rare for any measurements of such flows to be made, by any means and in any quantities, with a greater degree of accuracy.

The uniformity of the scale of such an instrument depends, naturally, on the taper of the tube. With a uniformly tapered tube, the change in the rate of increase of the annular area around the float is such that equal increments of the height of the float are concomitant with increasing increments of flow. As a result of this there is a practical limit to the scale ratio $\left(\frac{\text{maximum reading}}{\text{minimum reading}}\right)$, generally not exceeding 10 : 1. In the case of large-sized instruments corrections for alteration in gas pressure follow the well-known square root relation, *i.e.*

$$\frac{V}{V_1} =$$

With the smaller instruments under discussion considerable variations from this law are discovered. Such variations are apparently due to differences in the internal friction of the gas and are incalculable, and only ascertainable empirically.

Fig. 2 shows the usual type of frame fitted to laboratory instruments. It is of the tripod type and fitted with levelling screws, as the vertical position of the tube is important. Where the fluid to be dealt with is of a corrosive nature the end connections are of glass throughout. The float in such a case is made of a suitable corrosion resisting material. Calcined steatite is frequently used, and also vulcanite, stainless steel, bronze and duralumin.

While this type of instrument is suitable for both liquids and gases, another type (Fig. 3), for liquids only, has also been designed. In this case the flow is downwards through the tube, which is larger in diameter at the bottom than at the top. The float in this case is a hollow glass cylinder, to which the rotational movement is imparted by means of spiral grooves in its upper part. In this case the velocity head of the liquid is opposed to the

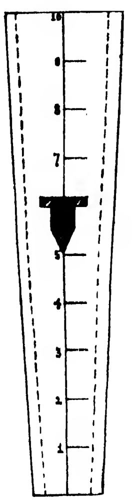


Fig. 1

Fig. 2

Fig. 3

buoyancy of the float, instead of its mass as in the usual upward-flow type. Down-flow instruments are usually supplied without frames, and are suitable for connection to rubber tubing and supporting in a retort stand.

The Rotameter has innumerable uses in a laboratory. It will be sufficient to mention two or three. In the Michie Sludge test for transformer oils, there is normally considerable difficulty in maintaining the necessary rate of flow of air. This is usually $2\frac{1}{2}$ litres per hour, and a small Rotameter will give this in the easiest possible manner. The laboratory chlorination of organic compounds can frequently be carried out more easily by the use of chlorine gas than by any other means. Strict control of all the conditions is necessary for successful results, and control of the rate of flow can most easily and accurately be effected by the Rotameter. Control of water flows in experiments on elutriation is simply and accurately obtained by means of the inverted type of Rotameter.

A NEW PORTABLE POTENTIOMETER.

By D. C. GALL.

A NEW portable potentiometer has been constructed by Messrs H. Tinsley & Co., Werndee Hall, South Norwood, S.E. 25, designed to have the full sensitivity available with the more elaborate set-up usually restricted to the laboratory. To achieve this a reflecting galvanometer has been embodied in the instrument itself, together with a 2-volt accumulator and a standard cell. The potentiometer is thus completely self-contained.

Fig. 1. Portable potentiometer

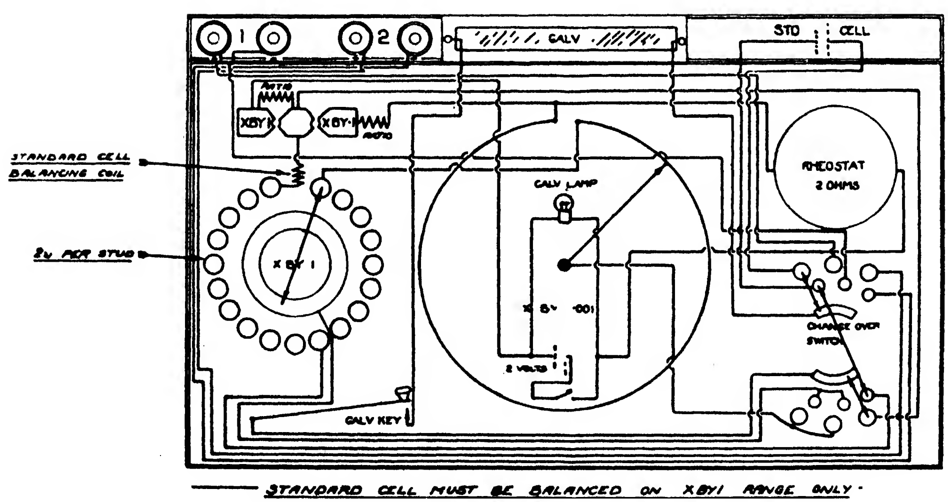


Fig. 2. Diagram of connections

The galvanometer is the same type as the self-contained reflecting instrument made by Messrs Tinsley. The coil has a tight suspension so that level is not important. The illuminated "spot" appears above the dials upon a graduated scale. The scale distance is 13 cm. and the sensitivity 10 mm. deflection per micro-ampere with a 300-ohm coil. Lower

resistance coils can be used for low resistance circuits by means of interchangeable suspension pieces supplied for the purpose. The normal range of measurement of the potentiometer is a maximum of 1·8 volts readable to 0·0001 volt, with a second range of 0·18 volt readable to 0·00001 volt.

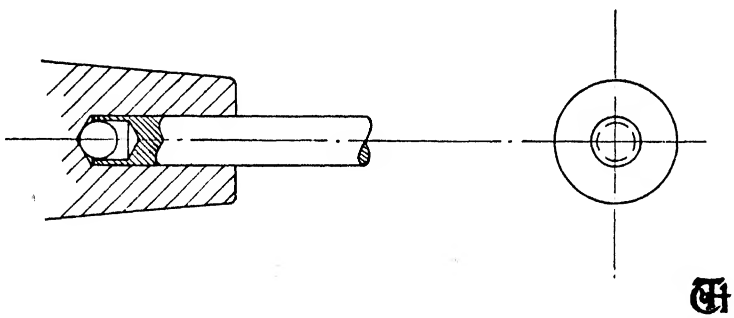
For thermo-couple work a low range instrument may be preferred having ranges of one-tenth the above. All three ranges can be provided in the one instrument if specially required.

The potentiometer has two pairs of test terminals for measuring the unknown E.M.F.'s, which are selected by means of a switch. This switch has a third position for standardizing the potentiometer against the standard cell. The setting of the standard cell is independent of the potentiometer dials, so that the standardization can be checked in a few seconds without disturbing the measurements. The 2-volt accumulator (of the unspillable type) supplies the potentiometer and the galvanometer lamp. The total weight is $15\frac{1}{2}$ lbs. and the overall size $15'' \times 9\frac{1}{2}'' \times 9\frac{1}{4}''$. Fig. 1 gives a general view of the instrument and Fig. 2 illustrates the connections.

LABORATORY AND WORKSHOP NOTES

RIVETTING INTO A BLIND HOLE

THE illustration shows an ingenious method, due we believe to John E. Sweet, of upsetting a pin into the bottom of a hole. The pin is drilled at the bottom slightly smaller in diameter than the ball. This is an ordinary steel bearing ball, which, when the pin is driven down,



expands it, upsetting it into the hole. If the bottom of the hole is first chambered, using a wobble drill, an even securer job can be made. Not only does this method make a simpler and cheaper job than screwing, but the pin will be true in the hole and will never come loose.

THE TAYLOR-HOBSON RESEARCH LABORATORY,
LEICESTER.

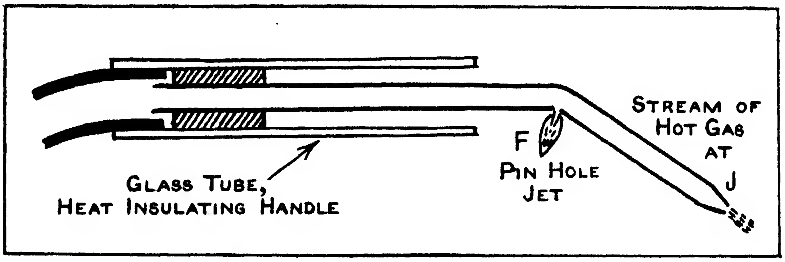
AN AID IN SOLDERING SMALL PARTS.

BY WILLIAM CLARKSON, PH.D., M.SC.

AN interesting and highly useful small tool for the warming of small or inaccessible parts of instruments preliminary to soldering was recently brought to the writer's notice.

A length, say 20 cm., of 3–4 mm. brass tubing is connected, preferably through a cork or some such heat-insulating material, to a gas supply (see diagram), and so bent that the stream of gas issuing from the end *J*, which should be made of suitable proportions, may

be played on such metal parts as are to be soldered. At a convenient place in the tube, here at the bend *F*, a pin-hole gas jet is made, where the gas is lighted, so that the tube becomes very hot. This heating is communicated to the stream of gas in the tube and thus in turn to the parts to be soldered.



Though a metal rod mounted and heated like the small soldering-bolt previously described by the writer* is also very suitable for the same purpose the method here described has much to recommend it. For one thing the heating is not so fierce, and further, fragile parts are not subjected to strain. The diagram shows how connections may be made in a glass tube, which, sheathing the hot metal, acts as a convenient and heat-insulating handle.

CORRESPONDENCE

THE PHOTOMETER BENCH

I HAVE read Mr Sutton's paper in the June number of the *Journal* with great interest because, of course, he is quite right in saying that most of the photometer benches which used to be available were quite unsuited for work of any accuracy. At the same time he does not seem to be aware that there is on the market at the present time a bench which has been specially designed for work of the highest precision. This bench is manufactured by Messrs Alexander Wright & Company, of Westminster, and it completely satisfies all Mr Sutton's eight requirements, except Nos. (3) and (5), but including his suggestion for two spool-shaped and one cylindrical wheel on the "trolleys" or carriages.

The reason for the exceptions is that the bench is designed for a method of working which differs somewhat from that described by Mr Sutton, and in which one lamp is lined up over the zero mark on the bench scale (so that the pointer does not function in this case) while the other lamp moves with the photometer head. It is the position of this head which has to be noted at each setting, so clearly some auxiliary lighting of the pointer must be provided if this method is used and, further, this is the only pointer the position of which is important, and it can be adjusted once for all to suit the photometer head used.

There is a further requirement that I should have added to Mr Sutton's list and this also is satisfied in the Wright bench; I mean provision for a very accurate and, if necessary, gradual rotational adjustment of the lamps and photometer head. Anyone who has worked with standards set in position by means of circles etched on the bulb will appreciate the necessity for this movement.

The device for distant control of one carriage needs very careful design, particularly as regards the avoidance of slip and backlash. Either of these, if present in any noticeable amount, entirely destroys the accuracy of the photometric setting.

* *Journ. Sci. Insts.* 4 (1927) 395.

In conclusion I should like to say that I think Mr Sutton's paper is most useful in pointing out the fact, only too frequently ignored, that a photometer bench is a piece of apparatus which requires careful design and accurate workmanship if it is to give satisfactory service.

JOHN W. T. WALSH.

THE NATIONAL PHYSICAL LABORATORY,
TEDDINGTON, MIDDLESEX.

I AM glad to receive the comments of so eminent an authority on photometry as Dr J. W. T. Walsh and appreciate his encouraging remarks.

I was certainly unaware that the bench manufactured by Messrs Alexander Wright had any means for lining up either the photometer disc or the lamp filaments with a point on the scale. In a bench of that type installed at the City and Guilds (Engineering) College it has been necessary to arrange a framework with plumb lines for the purpose.

I should perhaps emphasize that in constructing the bench I have described I departed from the former design only from consideration of cost and simplicity, since it is intended more for the purpose of teaching the principles of accurate measurements than for routine work of high precision. The bench is being placed on the market by Messrs Baird and Tatlock at a cost of about £30, which is of course far below the price at which the former type could be manufactured. At the same time I must apologize for omitting a reference to a bench of such excellent design.

I have not described the device for distant control of one carriage; it is worked on the endless band principle with a spring at one end to take up backlash and is quite satisfactory in operation. I agree with Dr Walsh that it is a desirable feature to have a device for slow rotational motion of the lamp or photometer head.

JOHN F. SUTTON.

CITY AND GUILDS (ENGINEERING) COLLEGE,
EXHIBITION ROAD, LONDON, S.W.

THE STRAIGHT LINE RHEOSTAT

I HAVE read with much interest the article by Dr D. T. Harris in the May issue of the *Journal*, entitled "Continuous Reading of Varying Potentials by Means of Thermionic Valves." On pp. 163 and 164 mention is made of a straight line rheostat, the general principle of which is given in Fig. 7. I would like to state that my firm, Messrs Claude Lyons, Ltd., are the sole European agents for this rheostat, which is covered by various patents, and is made by Messrs The Electrical Engineers Equipment Co., of Chicago, Illinois, U.S.A.

Such an instrument is frequently of considerable value in the laboratory. The "3 E" rheostat, which is made in three sizes, of 6, 15 and 30 ohms maximum resistance, is illustrated in the Fig. The principle upon which this "3 E" rheostat works is very simple. The resistance is varied by winding the resistance wire from a short-circuiting aluminium cylinder on to an insulating cylinder of moulded bakelite, and *vice versa*. Naturally the more wire there is on the insulated cylinder the higher is the resistance in circuit. It takes 24 complete turns of the operating knob to wind from minimum to maximum, every millimetre of the wire being traversed, thus giving an exceedingly good micrometer adjustment. In service, of course, only one or two turns are generally required.

The wire is kept taut by means of a torsion spring inside the metal cylinder. The minimum resistance is very low, about 0·15 ohm, this being accomplished by sweating a small copper wire in parallel with the resistance wire for a short distance, at the minimum end. Once the instrument is set it will maintain a practically constant resistance except for a negligible increase due to temperature rise if somewhat overloaded. An "off" position is very ingeniously arranged. The central spindle is threaded through a bakelite "flier," and as the spindle is rotated the flier progresses along it, being free to move but not to rotate. Eventually it is worked right along the spindle until it lifts one of the contacts.

The device is not very new; we have been importing and distributing these rheostats for nearly three years, and have supplied many laboratories, including a specimen or two to the National Physical Laboratory.

CLAUDE L. LYONS.

OLD HALL CHAMBERS,
76, OLDHALL STREET, LIVERPOOL.

RECENT RESEARCHES AT THE NATIONAL PHYSICAL LABORATORY

The National Physical Laboratory. Report for the Year 1927. Pp. vi + 264. London: H.M. Stationery Office. Price 7*s*. 6*d*. net.

(*Continued from p.* 203.)

ELECTRICITY DEPARTMENT

The Measurement of Amplifying Systems. As a result of the experience gained in the numerous tests on the valve apparatus used in this investigation, the method has been brought to greater perfection, so that accurate measurements of the ratio and phase relationships of input and output voltages of valve amplifiers can be made over the whole range of acoustic frequencies, even for amplifications of several thousand.

The arrangements are such that each part of an amplifying system may be measured at its input and output ends without interfering with its normal behaviour. The effects of intentional and of parasitic retro-action can be studied in a quantitative manner. The system incorporates a special earthing arrangement whereby the earth capacities associated with the detecting device—telephone or vibration galvanometer—are rendered of no effect. A special mutual inductance with a twin-wound secondary coil enables the detecting device to be maintained at earth potential without the necessity of actually setting a preliminary and auxiliary balance, as is usually necessary when a Wagner earthing device is used.

During the year the bridge used for the measurement of high inductances found extended application in the investigation of the effect of superimposed direct current upon the A.C. inductance of iron-core inductances. This would appear to be a fruitful field for further research. This bridge has also demonstrated that the leakage field of an intervalve transformer is located entirely in the air, and that it is independent of the direct current flowing through the windings.

The Mutual Conductances of Thermionic Valves. A bridge method for the direct measurement of the mutual conductances of thermionic valves has been devised. Alternating current of telephonic frequency is used, and the measurement can be made with any desired value of grid bias, so that the value can be obtained under actual working conditions. The bridge is very rapid in operation and is direct reading.

Study of Magnetic Phenomena in Iron and its Alloys. In continuation of the study of fundamental phenomena of magnetism which is being carried out in collaboration with the Metallurgy Department, a number of measurements of permeability and hysteresis have been made on samples of iron of very high purity. The samples were of ring form, in most cases consisting of a single ring

about 3 cm. in diameter and 0·1 sq. cm. in cross section, but in certain instances they were built up of several rings of sheet material.

The results obtained varied over a wide range. The best sample had a maximum permeability of approximately 29,000 and a hysteresis loss, for $B_{max} = 10{,}000$, of only 460 ergs per c.c. per cycle, but other specimens of equal chemical purity gave maximum permeabilities of the order of 8000 with hysteresis losses of the order of 1000 ergs per c.c. per cycle. Attempts have been made to determine the cause of these variations in the magnetic properties of practically pure iron by varying the heat treatment, rate of cooling, etc., but up to the present no conclusive results have been obtained.

Testing of Sheet Samples at Low Magnetizing Forces. It is well known that the magnetic properties of iron and steel samples may be altered considerably by the application of mechanical stress to the material. Sheet material is particularly liable to such effects since a small force may produce sufficient bending in a thin sheet to cause fairly large stresses.

In the course of the investigation into the use of the yoke tester at low magnetizing forces a number of measurements were made on sheet samples to determine the causes of error: with rings and strips of material of high permeability, the stresses produced merely by binding the sample with insulating tape preparatory to winding on search-coils might cause an increase in the value of H for a given B of as much as 30 per cent., the alteration being a maximum for values of B between 10,000 and 12,000.

Alternating Current Permeability. The work previously carried out on the influence of frequency and form factor on the value of the ratio B_{max}/H_{max}, and on the agreement between this value and the D.C. permeability, has been extended and completed, and the previous conclusions have been confirmed, viz., that apart from the influence of eddy-currents, the value of B_{max}/H_{max}, or A.C. permeability, is practically independent of frequency and form factor and agrees closely with the D.C. permeability.

In addition to direct measurements of H_{max} and B_{max} by the use of a synchronous commutator, a number of complete hysteresis loops under A.C. magnetization were plotted by a point-by-point method for comparison with the corresponding D.C. loops, and confirmed ou[illegible]clusions deduced from the permeability readings. The accuracy of the synchronous commutne[illegible]hod of obtaining readings was checked by comparing the wave-shape given by this methoh[illegible] that shown by an oscillograph. It is hoped to publish a paper on this subject in the near fut[illegible].

Deterioration of Ebonite. The surface deterioration of ebonite under the influence of ultra-violet light was investigated in a few cases. For this purpose, measurements of surface resistivity were made on the samples before and after exposure to the light from a mercury arc for about 12 hours. The surface resistivity of one piece of ebonite was reduced to about one-millionth part of its original value by this exposure. The surface became coated with a kind of "bloom" just as it does on prolonged exposure to ordinary sunlight, and it is probable that such measurements will provide a rapid means of testing the power of ebonite to withstand the action of sunlight.

Standard Resistances. During the year an examination has been made of a series of observations, extending over some three years, on a number of "Ohmal" resistances made by commercial firms at the instance of the British Scientific Instrument Research Association. In cases where the mechanical construction of the individual resistances is suitable for the study of their stability, the results show that the changes have been probably of the order of not more than about one part in 100,000.

One of the important requirements in the measurement of standard resistances is a knowledge of the temperature to a sufficient accuracy; if the temperature coefficient of the resistance is large, then the accuracy of the temperature measurement must be increased. A resistance having nearly zero coefficient at the working temperature has therefore a great advantage, in that the temperature need not be known so accurately; there is also a considerable saving in the time required for the temperature to reach a sufficiently accurate known value. The "Ohmal" used for the build-up resistances already mentioned has a negative temperature coefficient. If a material with a positive coefficient is substituted for some of it, it is possible to construct a composite resistance having the same value at any two desired temperatures. If the two temperatures chosen are equidistant from the working temperature, the rate of change at the working temperature will be very small, even if the characteristics of the two materials are different.

High Voltage Laboratory. Early in the year the final details of the three high-voltage transformers, which are the principal items of the plant for the high-voltage laboratory, were settled between the contractors, H.M. Office of Works, and the Laboratory, and construction was commenced.

The heavier parts, including the iron cores and insulating stands, have been delivered. The more delicate parts, such as the secondary windings, will be delivered as soon as the erection of the heavier parts is well in hand. It is important to be able to take a direct lift over each of the cores of each transformer for ease and safety in erection, etc., and the most economical design of equipment for doing this has been carefully looked into by H.M. Office of Works and the Laboratory. A scheme involving a straight runway along the building, dividing into two branches over the transformers, was decided upon. The erection of this is approaching completion. It will permit of loads up to three tons being lifted and traversed by operating a stationary controller on the ground. The controller is arranged at the edge of the transformer pit to enable the operator to have as good a view as possible. The connecting cables are carried to it in a trench in the floor, and a disconnecting box is arranged so that the controller can be removed when desired. The generating plant has been inspected in the maker's works during construction, and it is expected that it will very shortly be ready for the contract tests. Special consideration has been given to the provision of the different arrangements which may be required for connections between the generators, the primary circuits of the transformers, and the main switches controlling them. A large variety of single, two-phase, three-phase and cascade connections will be necessary, both as regards the generating and transforming plant.

Resistor for High Voltage Measurements. The accurate measurement of electrical quantities on high-voltage circuits frequently requires the use of a resistance which is virtually free from inductance and, what is more difficult to obtain, from the effects of earth capacity and stray capacity. A scheme for the design of such a resistance was described in last year's Report, the resistor being divided into sections each enclosed in a metal case. The case is arranged to have a definite potential very close to the average potential of the section of the resistor which it contains, by connecting it to a suitable point of a second similar resistor also capable of withstanding the whole voltage. It was explained that this arrangement was only suitable for a certain limited voltage, since the phase angle, though small for moderate voltages, increases very rapidly when the apparatus is extended to higher voltages. To avoid this, it was suggested that the secondary resistor might also be enclosed in a series of metal cases, which themselves would be supplied from suitable points of the high-voltage winding of the power transformer.

A further development of this arrangement, which it is intended to adopt, is to protect the measuring circuit completely from the influence of capacitance to earth by enclosing each of its units in the metal case containing the corresponding section of the subsidiary resistance. Experiments have been carried out on trial units designed to investigate the best method of construction.

In electrical apparatus of this character it is important to keep as high as possible the ratio of the rated current to any adventitious capacitance currents, to which the chief errors of importance are due. To achieve this for a given general geometric configuration, it is of advantage to use as large a power current as is practicable, with due regard to the temperature rise involved. It has therefore been necessary to measure the temperature rise which may be expected in the various parts of the apparatus made according to the design proposed.

The choice of material for wire suitable for a resistor of this nature depends primarily on its very low change of resistance with temperature; this must be so small that the resistance of the wire cannot be used as a sufficient indication of its temperature. Experiments have therefore been made using a material of the same diameter, and covered in the same manner but having a relatively very large change of resistance with temperature. Measurements of the current and voltage give the value of the resistance under the conditions of the experiment. From this the temperature can be accurately deduced, and if it is arranged that the power dissipated is the same as in the case of the resistor itself, the temperature will also be the same. Copper was chosen for the purpose, but as its specific resistance is only about one twenty-fifth of that of a suitable resistance alloy, the rated power consumption and the corresponding temperature will be obtained if the voltage applied to a copper circuit is about one-fifth of that applied to a circuit of identical form made of resistance alloy.

Dielectric Losses at High Voltages. Different methods have been used for measuring the power dissipated in circuits having a power factor of the order of 0·01, and tests have been made up to 20 kilovolts. For voltages of 150 kilovolts and upwards a new three-plate condenser has been designed with variable spacing and guard ring. To avoid brush discharge at the sharp edges an investigation was made by immersing metal models of the plates in a weak electrolyte and applying A.C. at audio-frequency: an exploring platinum electrode and telephone were used to map out the equipotential surfaces.

Investigation of the Propagation of Wireless Waves. The polarization of waves has become the principal object of study. During the total eclipse no abnormal polarization was noticed for long waves outside the path of totality, but a reduction in absorption occurred. For medium waves rotations of apparent bearing of as much as 180° have been observed. The height of the Heaviside layer has been deduced as about 100 kilometres.

Rotating Beacons. The rotating beacon system of directional transmission has been developed to a high degree in this country by the Royal Air Force, as a method of applying wireless transmission to the navigation of aircraft. With the object of examining the performance of this type of beacon from the standpoint of its utility to marine navigation, an experimental beacon was erected by the Air Ministry at Fort Monckton, near Gosport, in July, 1926, and lent to the Department of Scientific and Industrial Research. The experiments in this connection have been carried out under the supervision of the staff of the Division, and the main portion of the investigation was completed in October, 1927.

This type of rotating beacon transmitter employs a vertical frame coil rotating at a uniform speed about a vertical axis. The coil is fed with radio-frequency oscillations from a suitable valve transmitter, and the radiation in any direction varies as the cosine of the angle between the direction and the plane of the coil. Thus the signal intensity at a fixed receiving point varies from a maximum when the plane of the coil is in the direction of the receiver to a minimum or zero when the coil is perpendicular to the direction of the receiver. Bearings are obtained on this transmitter by observing the time at which the signal minimum occurs after the transmission of a characteristic signal, which is sent when the plane of the coil is perpendicular to the geographical meridian. From a knowledge of the time of rotation of the coil, usually sixty seconds, the bearing of the receiver from the transmitter can be calculated. The bearing so obtained can be checked for every 180° rotation of the coil, *i.e.*, at half-minute intervals.

Taking the somewhat conservative figure of 50 miles as the reliable working range of the beacon for accurate bearings by both day and night, it was found that the present beacon gives adequate signal strength on continuous waves for observation at this range on a typical ship's receiver, except in the most unfavourable conditions of heavy interference. With interrupted continuous wave transmission to a non-oscillating receiver, the limiting working range may be reduced to 20 miles or less according to the interference conditions.

Research on Short Waves. Work has been continued during the year in investigating the fundamental technique of transmission and reception on short wave-lengths. Particular attention has been given to wave-lengths below 25 metres. On the very short wave-lengths below 10 metres care must be taken with the design of the oscillators, owing to the possibility of the formation of stationary waves on the conductors and coils. The coupling between two coils carrying stationary waves depends on the relative positions of the antinodes of current and potential. For a given setting of two coils the degree of inductive coupling is a maximum if the distance between the antinodes of current in the two coils is a minimum. If capacitative coupling is used the degree of coupling is governed by the relative positions of the antinodes of potential. The introduction of condensers, or even the varying of a condenser in a circuit, may change the positions of antinodes of current and potential and so alter the coefficient of coupling with another coil.

Photometry. By the use of the alkali-metal photoelectric cell the accuracy of measurements of relative intensity is two or three times as great as that given by visual measurements, and for colour matching the precision is 0·1 per cent. The carbon tube vacuum furnace has been used as a standard of energy distribution up to 2700° K. The effect of the geometric form of photometric integrators has been measured: the values of mean spherical candle power obtained in a plain cube were of the order of 1 per cent. higher than those obtained in a sphere, while the values obtained in a cube with the corners filled in were about 2 per cent. higher than the sphere values.

R. T. B.

(*To be continued.*)

REVIEW

Measurement of Air Flow. By E. OWER, B.Sc. (LOND.), A.C.G.I. London: Chapman and Hall, Ltd. Pp. vii + 199. Price 15*s*. net.

The estimation of a flow of air or other gas is a problem which occurs in various branches of engineering with a frequency which is probably not realized by the average physicist, and there is certainly a place for an adequate book on the subject. The aim of the author has been to present to the practical engineer methods of measurement of proved accuracy unencumbered by accounts of out-of-date experiments. The need for reliable information on the subject, however, is much more widespread than he has realized, for he has confined his attention almost entirely to the fan and ventilating engineer. Methods of measuring a steady flow of air in wind channels, mines and pipes are subjects on which the author himself has done much original work; and accounts of the pitot tube, the vane anemometer and orifice restrictions in pipe lines comprise about eighty per cent. of the book. The collection and presentation of the most recent work on these subjects is to be commended. The design of pitot tubes and the effects of shape of head and of position on the readings are dealt with in a full and readable manner. Although many users of pitot tubes are aware in a general way of the faults to be avoided, the quantitative information on the effect of errors of design and of inclination is not usually available to them. The theory of the vane anemometer, which is given at considerable length, is also a subject which finds little or no place in other books on wind and draught measurement. It is doubtful, however, whether the mathematics will make much appeal to the practical engineer to whom the book is addressed.

A chapter on the flow of air in pipes gives an account of Stanton and Pannell's classical work and is followed by descriptions of the use of the plate orifice, venturi tube and shaped nozzle placed in pipes for the measurement of the air. The author has avoided the overloading of this chapter with the data obtained by the numerous experimenters who have made tests under slightly dissimilar conditions. Selecting the results which he considers the most reliable, he has given, for each method, one form of apparatus with dimensions and appropriate constants. Many students of hydraulics will wish that authors writing on the flow of water would follow his example! The final chapter of the book deals with electrical methods of measuring air flow, but principles only are briefly described and a bibliography, incomplete, is added. Descriptions of actual instruments, particularly of the Thomas meter, which is in use in many gas plants in the United States and in Europe, would have been of service.

The defects of the book are of omission rather than of commission, but in view of the general title given to the work, they can scarcely be dismissed as venial. The problem of fluctuating air flow is very inadequately treated. A mathematical examination of the effect upon the vane anemometer shows that the reading obtained will be in excess of that which would be given by the same average constant flow, but no indication is given as to methods of detecting errors due to this cause. A method for equalizing damping on both sides of a pitot tube in order to obtain a true mean static pressure is given, but beyond a statement that the velocity head on the pitot tube may also vary, no reference is made to the errors in the mean velocity head reading due to such variation. The errors in any pressure method of measuring the air consumption of an internal combustion engine may be very great, owing to the fluctuation in velocity, unless some means are introduced between engine and instrument for damping out the pulsations. No mention is made in the book of the work of Durley, whose data are used as standard in engine tests in the United States, or of Watson, whose figures are used in England.

The meteorologist is dismissed a little less summarily than the internal combustion engineer, for he receives a single paragraph of description on the cup wind gauge. There is a chapter of nearly thirty pages on manometers, but it is confined to liquid manometers for very small pressures. Nothing is given on the precautions by means of which an ordinary U tube gauge can be made sufficiently accurate at pressures of (say) two inches of water, while the air-speed indicators used in conjunction with the pitot tube on every aircraft are not mentioned.

Although the ground which the book does not cover would thus appear to be considerable, the book can be recommended for those parts of the subject which the author has made his peculiar study. To anyone whose work necessitates the use of pitot tubes, the book would be extremely useful, while the account of the steady flow of air and its measurement in pipes is concise and readily applicable. The book is well printed and bound, but the price is excessive. H. M.

THE ROYAL OBSERVATORY, GREENWICH

A REFLECTING SPECTROGRAPH FOR SPECTRO-PHOTOMETRY. By C. DAVIDSON, F.R.A.S.

An interesting research carried on at the Royal Observatory in recent years, which was demonstrated to those who attended the Annual Visitation on June 2nd, has been the determination of the colour-temperatures of stars from a consideration of the distribution of the light intensity in the continuous spectrum. This work has been carried on with the 30-inch reflector with a slitless spectrograph attached, and as there are some slightly novel features in the latter a short description of the optical train may be of interest. It is illustrated in Fig. 1.

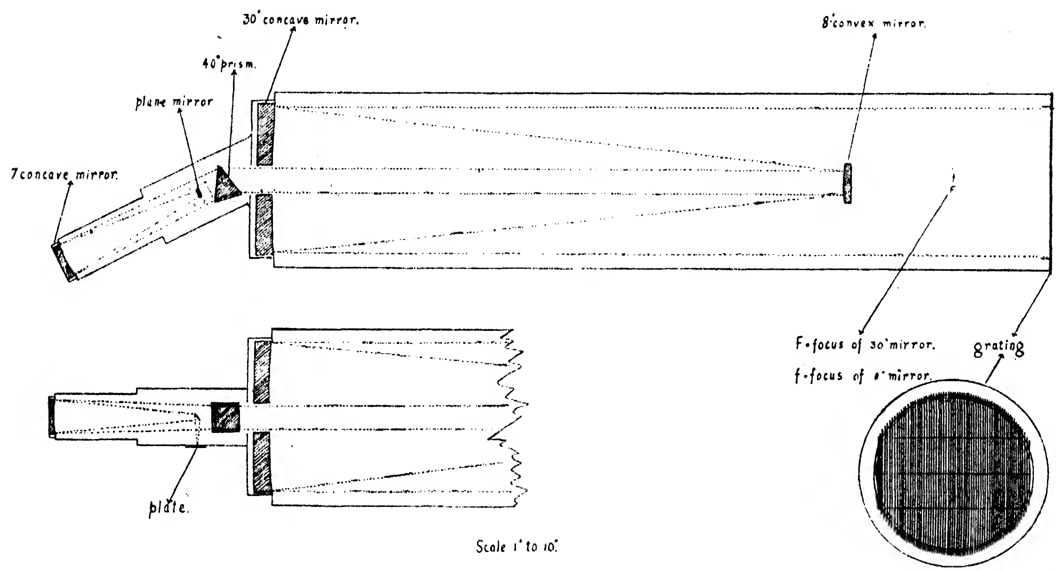


Fig. 1. 30-inch reflector with spectrograph

The 30-inch mirror, which is designed to be used in Cassegrain form, has a 6-inch hole in the centre. The focal length of the large mirror is 137 inches and that of the small convex is 24 inches, so that when the convex is placed with its focus coinciding with the focus of the large mirror, a parallel beam $5\frac{1}{2}$ inches in diameter is sent through the central hole. Just behind the great mirror the beam falls on a prism of 7 inches height and 40° angle. As originally constructed, after passing the prism the rays were focussed by a triplet lens of 6 inches aperture and 27 inches focus. This lens was photographically corrected, and in the blue region gave excellent definition, but in the yellow and red regions the spectra were hopelessly out of focus. As the accuracy of the method depends to some extent on the length of baseline or the range of wave-length it was desirable to re-design the apparatus so that the red should be brought into focus with the blue.

The lens was therefore replaced by a concave mirror, $7\frac{1}{4}$ inches in diameter and 35 inches focus, on which the beam falls and is then condensed to focus near the prism. At 6 inches inside focus, the light falls on a small plane diagonal reflector which directs it on to the photographic plate placed at the side of the camera. The optical path is made clear in the

accompanying diagram (Fig. 1). By this scheme one is able to take full advantage of the light grasp of the 30-inch mirror together with the dispersion of the 40° prism; also by using a mirror in the spectrograph it is possible to obtain good definition throughout the whole range of the spectrum.

The prism is about 35 inches from the condensing mirror, and the dispersion is such that the scale of the spectra is 30 mm. from λ 3968 to λ 6563, so that between these limits the 7-inch mirror returns a full beam. The diagonal is, of course, of suitable breadth to receive the same length of spectrum. The spectrum is widened to suitable width ($\frac{1}{2}$ mm.) for measurement by moving the plate transversely to the spectrum by a micrometer screw.

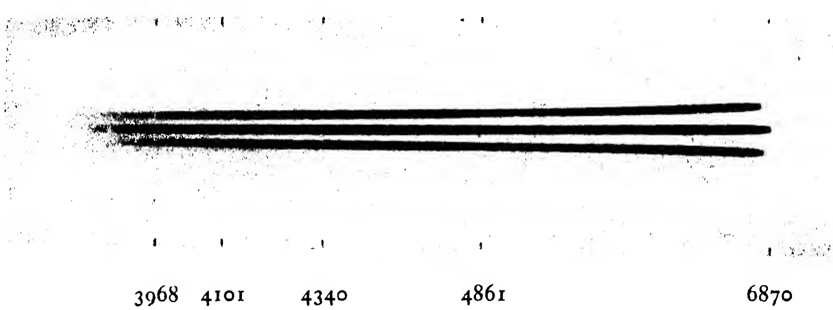


Fig. 2. Spectrum of α-Cygni taken with reflecting spectrograph prism crossed by grating

In spectrophotometry it is essential that the plate should carry a scale whereby the relative density of the photographic deposit may be translated into relative light intensity at any wave-length. This is done by means of a coarse wire diffraction grating which is placed over the mouth of the tube of the reflector with its dispersion crossing that of the prism. The wires are 1·5 mm. diameter spaced at 3·0 mm. intervals, *i.e.* bar and space are equal. By this arrangement there is a difference of light intensity between the central spectrum and the first order lateral spectrum of 2·5 : 1 or 0·98 of a stellar magnitude, which provides the unit by which the difference of density at any wave-length may be converted into difference of magnitude or relative light intensity.

An example of a stellar spectrum with this apparatus is shown in Fig. 2.

THE NATIONAL PHYSICAL LABORATORY

THE Annual Inspection by the General Board of the Laboratory took place on June 26th. Visitors were received in the Main Aerodynamics Building by Sir Ernest Rutherford, O.M., President of the Royal Society, Chairman of the Board, Sir Richard Glazebrook, K.C.B., F.R.S., Chairman of the Executive Committee, and Sir Joseph Petavel, K.B.E., F.R.S., Director of the Laboratory.

Much interest was shown in the equipment of the new High Voltage Laboratory of the Electricity Department, in which the three high voltage transformers, giving voltages up to a million, were seen in operation for the first time. All Departments of the Laboratory were open to inspection, but detailed description of the experiments in progress is not called for here, since a summary of "Recent Researches at the National Physical Laboratory" is being given elsewhere in the *Journal*.

THE ROYAL SOCIETY

At the meeting of the Royal Society on June 21st, a paper on "Solid Dipleidoscope Prisms" was read by Mr C. V. Boys, F.R.S., of which the following abstract is given:

Bloxam's hollow prism, known as Dent's Dipleidoscope, is described. The general problem of the solid dipleidoscope prism is discussed. This instrument affords the best practical means of comparing the intensity of illumination of two images, and can be used to check the accuracy of Fresnel's equations for the intensity of light reflected from and traversing refracting surfaces. It is shown that the solid dipleidoscope prism might be used with advantage to increase the precision of our best astronomical instruments.

THE OPTICAL SOCIETY

In a paper read before the Optical Society on June 14th, Mr W. D. Wright, A.R.C.S., described a new "Trichromatic Colorimeter with Spectral Primaries." The instrument has been specially designed in order to make an accurate redetermination of the locus of the spectral colours in the colour triangle for as many observers as possible. A spectrometer system is used in which two spectra are formed from the same source. From one of these, three portions to act as primaries are reflected back through a lower part of the dispersing system, so that the mixing of the three radiations is effected by neutralizing the prismatic dispersion by which the colours were first separated. From the other spectrum the test colour and a desaturating colour are selected and mixed in a similar manner, and the composite beams are then brought into the two halves of a simple bipartite field. In the process of being mixed with the other colours, each spectral colour is filtered by its return passage through the dispersing system, and the instrument thus becomes very effective in removing stray light. Another device has enabled the Maxwellian method of observing the field of view to be adopted without the introduction of rotating parts into the system. The intensities of the three primaries are controlled with photometer wedges.

The paper will appear in full in the *Transactions of the Optical Society*.

CATALOGUES

The Cambridge Instrument Company, Ltd., 45, Grosvenor Place, London, S.W. 1, send an interesting brochure giving illustrations of a number of installations of Cambridge instruments in Heating and Ventilating Plants in public and private buildings.

Messrs A. Gallenkamp and Co., Ltd., 19 and 21, Sun Street, Finsbury Square, London, E.C. 2, have issued an Addenda List to the Eighth Edition of their Catalogue of General and Industrial Laboratory Apparatus. The list contains a number of important additions of new apparatus, and includes a list of price alterations which have taken place since the issue of the Eighth Edition.

Messrs Ogilvy and Co., 20, Mortimer Street, London, W. 1, send new lists of second-hand microscopes and other apparatus and accessories at considerably reduced prices.

Messrs Venner Time Switches, Ltd., 45, Horseferry Road, London, S.W. 1, have issued List No. 47 describing the Venner C and S Remote Water Level Indicator, by which boiler water level variations may be indicated at any convenient place remote from the boiler itself.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V | AUGUST, 1928 | No. 8

A UNIVERSAL X-RAY PHOTOGONIOMETER.

By J. D. BERNAL, B.A.

PART II*

[*MS. received*, *12th April*, 1928.]

ABSTRACT. Part II contains a detailed description of the X-ray Photogoniometer as manufactured by Messrs W. G. Pye and Co.; following which is a discussion of the principles involved in the construction of such an instrument. The three essential parts are treated separately. The requirements of an aperture system for X-rays are first dealt with, including a discussion of the shapes of spots due to the diffracted beams and of the conditions necessary to produce those of the greatest resolution and intensity. A similar discussion follows for the spindle and crystal holder, and lastly one on the arrangements for photographic registration.

As we have seen, the essential parts for taking rotation photographs are:

(1) A slit or hole system for limiting the size of the X-ray beam.

(2) A spindle on which the crystal may be suitably mounted and which can be uniformly rotated.

(3) A photographic plate or film which will record the direction of the reflected beams.

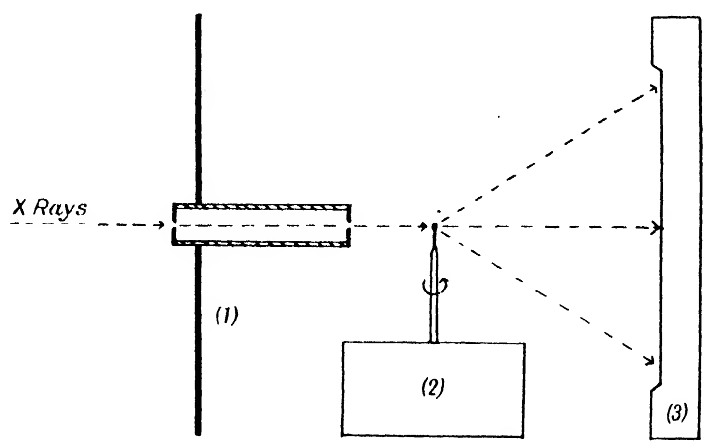


Fig. 1

Extremely simple instruments on these lines have been made to yield good results. One of these consisted only of (1) a brass tube passing through a lead screen having at each end a lead disc with a hole, (2) a clock mechanism on the minute axle of which the crystal was mounted, and (3) a quarter plate printing frame containing a plate wrapped in black paper; all mounted on a wooden base (see Fig. 1).

* Part I appeared in this *Journal*, 4 (June, 1927), No. 9.

It is obvious, however, that such an instrument is of little use when it is a matter of accuracy of results, exact repetition of conditions and rapidity and convenience of working. An instrument which fulfils all these conditions is being manufactured by Messrs W. G. Pye and Co., Granta Works, Cambridge, which is a development of one made by Mr Jenkinson of the Royal Institution workshop. A description of this instrument, which is illustrated in the figures, will furnish a basis for the discussion of the apparatus in general.

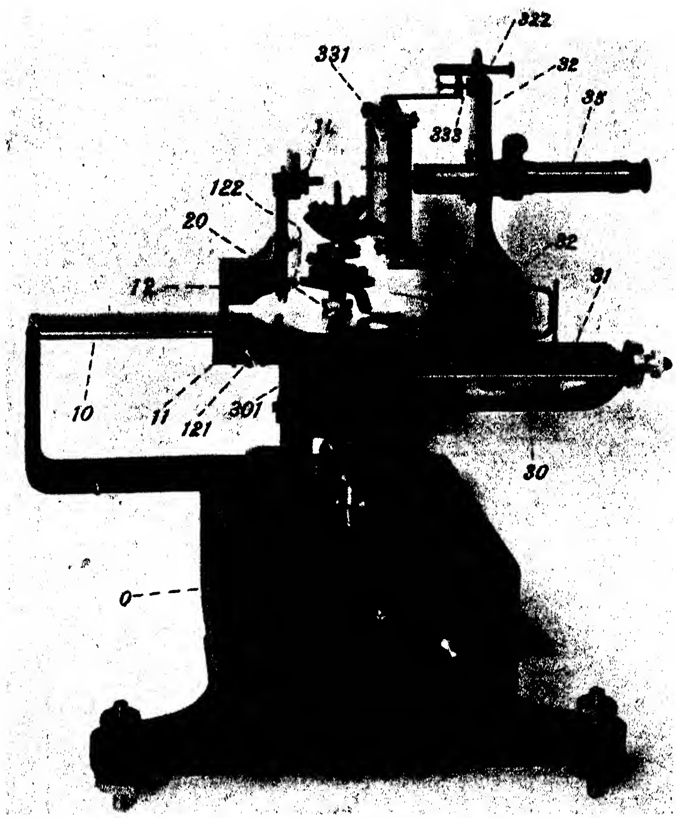


Fig. *A*. The instrument in normal working position for rotating crystal photographs with circular apertures and plane plate

Description of Instrument

The base of the apparatus (0) (see Figs. *A* to *H*) is a stout wooden box containing a powerful clockwork motor capable of running at a uniform speed for four or five hours. On it is screwed the heavy cast base of the instrument which carries the fixed slide (10) of the aperture carriage (11), the spindle (20), which is fitted with ball bearings to allow easy running and to prevent wear, the fixed divided circle (21) on which the angular positions

of the crystal and of the swinging arm may be read to 1′, and the swing arm (30) which supports the slide (31) of the plate carriage (32) and is clamped by the collar (301).

The aperture carriage (11) can slide along the fixed slide (10) and can be clamped in any position. On it the aperture holder (12) can be moved along a transverse slide by the screw (121). The aperture holder can be fitted with any of the following apertures:

The slit system (13) consisting essentially of two brass jaws which move on horizontal

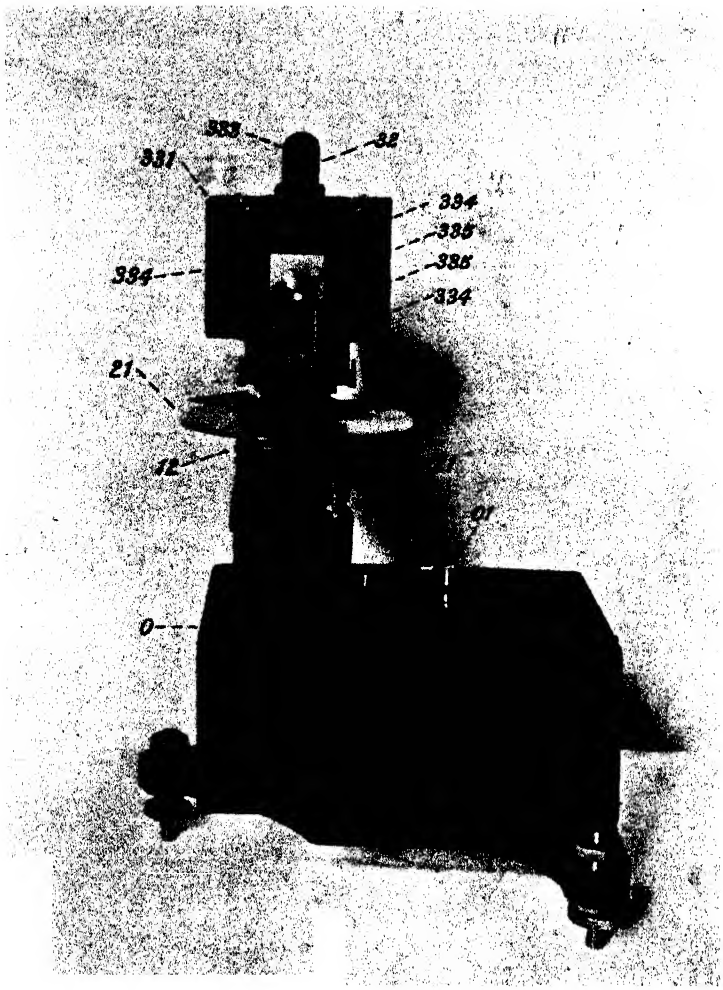


Fig. *B*. Same as Fig. *A*, end-on view

guides with a centering motion: the plane of the slits can be moved about a vertical axis by means of the adjusting screws (131). The slit system has as well two sets of horizontal slits (132), one pair fitted to the body of the slit holder, the other pair fixed separately to each of the jaws. This arrangement allows a rectangular beam to be passed through, which can be varied from a narrow horizontal to a vertical ribbon.

The tube (14) fitted at both ends with diaphragms whose effective apertures can be varied from 1 mm. to 0·2 mm. The barrel is adjustable in any direction by means of the three screws (141) which fit a geometrical clamp of the groove, hole and plane type, which

can also carry the collimator (15) of the normal optical goniometer type, with a Websky signal (152).

Both slit and aperture holder are mounted on two rods which slide into vertical grooves in the aperture holder, and are clamped with screws (122).

The spindle is a standard quarter inch rod; it may be coupled to the revolving shaft of the motor (01) either by the bevel wheels (02) for complete rotation at the rate of about 4

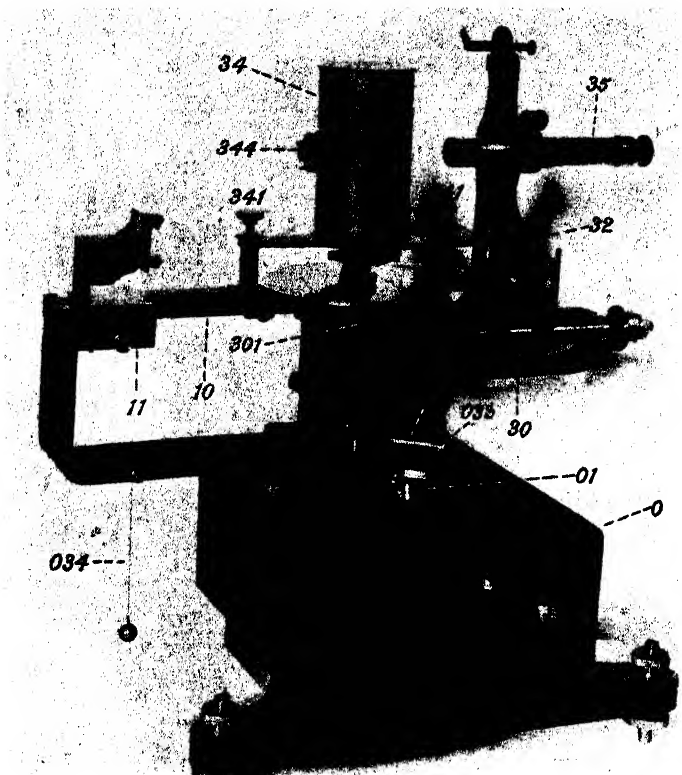


Fig. C. The instrument in working position for oscillating crystal photographs, with cylindrical film camera

per minute, or by the lever arm (03) and cam (033) for oscillation. There are three interchangeable cams (031, 032, 033) cut so as to give oscillations of uniform angular speed through the angles of 5°, 10° and 15°. The lever arm is held against the cam by the cord and weight (034). The use of a spring for this purpose has been found to produce non-uniform running by varying the torque on the motor at different parts of the oscillation. The spindle carries the goniometer head, which is in essentials the optical type, with a vernier (22) reading on the scale, a pair of cross slides (23) and a pair of arcs (24) graduated in degrees with verniers reading to 6′. These slides and arcs have been specially designed to be compact enough to allow the close approach of plate or film, with a large angular range of movement and obstructing the minimum solid angle between the crystal and the plate.

The goniometer arcs are attached to the cross slides by a 3-point geometric clamp, and in their place can be put a plate holder (25) for powders or spectrometric work, with an adjusting screw to bring its plane parallel to the axis; or a plain rod (26) which is useful for some purposes.

The plate carriage (32) slides along the slide (31) of the movable arm (30). In the instrument shown it is fitted with a micrometer screw, but the refinement is unnecessary

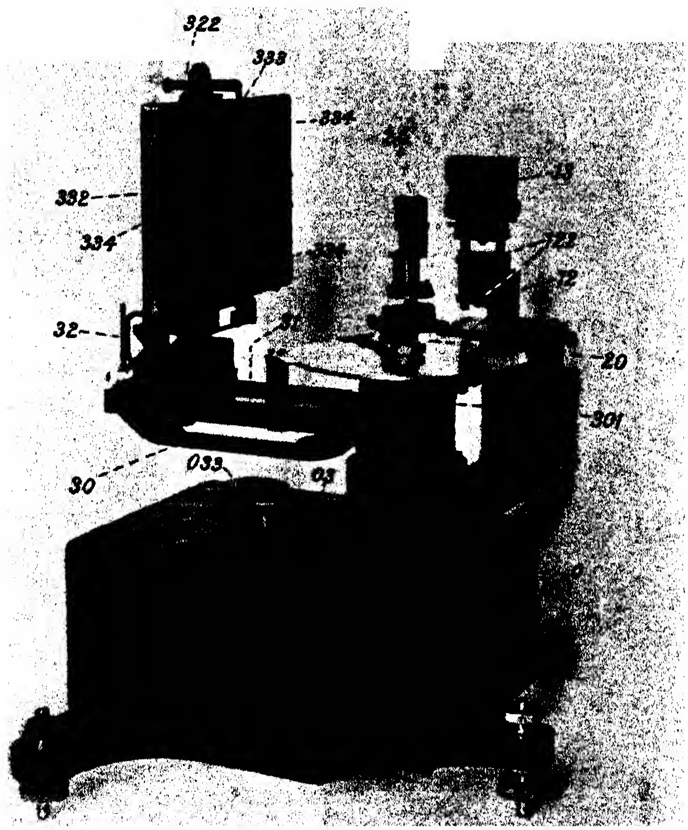


Fig. *D*. The instrument set up for spectroscopic photographs, with double slit system, crystal plate and arm carrying plate holder (half plate) turned through 90°

and even introduces errors due to backlash. The plate carriage serves three purposes: it supports the two plate holders and the cylindrical camera, and it carries the goniometer telescope and microscope. The plate holders (331, 332), one for quarter and one for half plates, rest on cylinders which engage in V grooves (321) in the carriage and are adjustable in the vertical plane, and at the same time rendered geometrically replaceable by the screw (333) which engages in a vertical groove at the top of the carriage and is held in place by a spring (322). The quarter plate holder is arranged to overhang so that it

may be brought within 3 cm. of the crystal without fouling any of the parts of the goniometer head.

The cylindrical camera (34) is supported on three screws (341), two of which engage in the grooves of the plate carriage. The third engages in a transverse groove which is adjustable and placed on a small bridge on the aperture slide.

The telescope (35), which by the addition of another objective lens becomes a low-power microscope, is adjustable with three screws and has a small transverse horizontal movement.

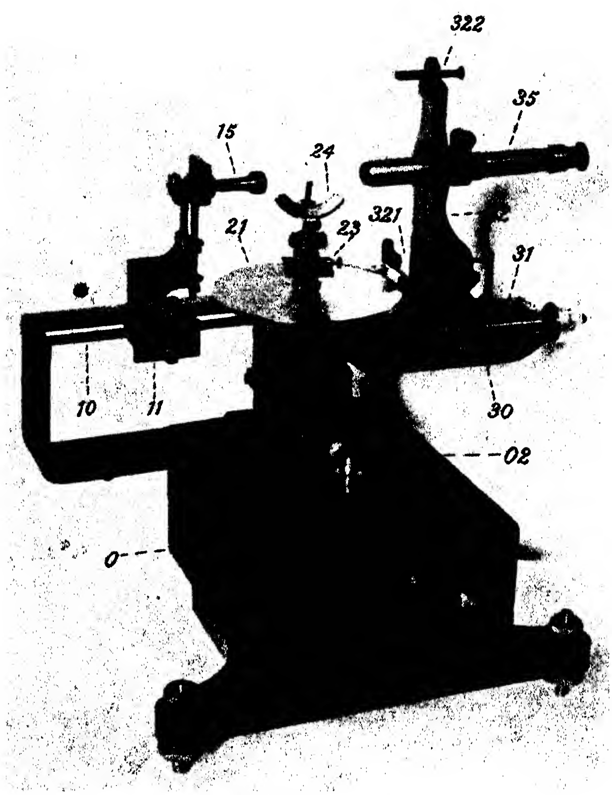


Fig. *E*. The instrument used as an optical goniometer, for setting up or measuring of crystals with collimator and telemicroscope instead of slit system and plate

The plate holders are made for quarter and half plates which are kept pressed against three small adjustable screws (334), thus assuring that the plane of the plate can be adjusted and fixed. Besides the three main screws there are two others (335) in the centre of the plate to carry strips of plate for spectroscopic work. The front of the holder must be covered by paper or opaque celluloid to render it light-tight.

The cylindrical camera carries its own aperture system (344) similar to (14); for compactness the film is held inside it by brass clips and it is shielded from the light by means of a celluloid strip and by a small box (not shown) which covers the upper edge of the film, leaving the centre free.

Theory of Instrument

The geometrical principles involved have already been given in Part I. They are given again here as a preliminary to more detailed treatment.

(1) The breadth and divergence of the incident beam of X-rays must be controllable.

(2) The axis of this beam must be perpendicular to the axis of rotation, and must intersect it at the point where the crystal is placed.

(3) The crystal must be capable of being centred on the axis of rotation and set at any desired angle to the axis of rotation and to the incident beam.

(4) The plate should be in its usual position normal to the incident beam or the cylindrical camera should have the axis of rotation as its axis.

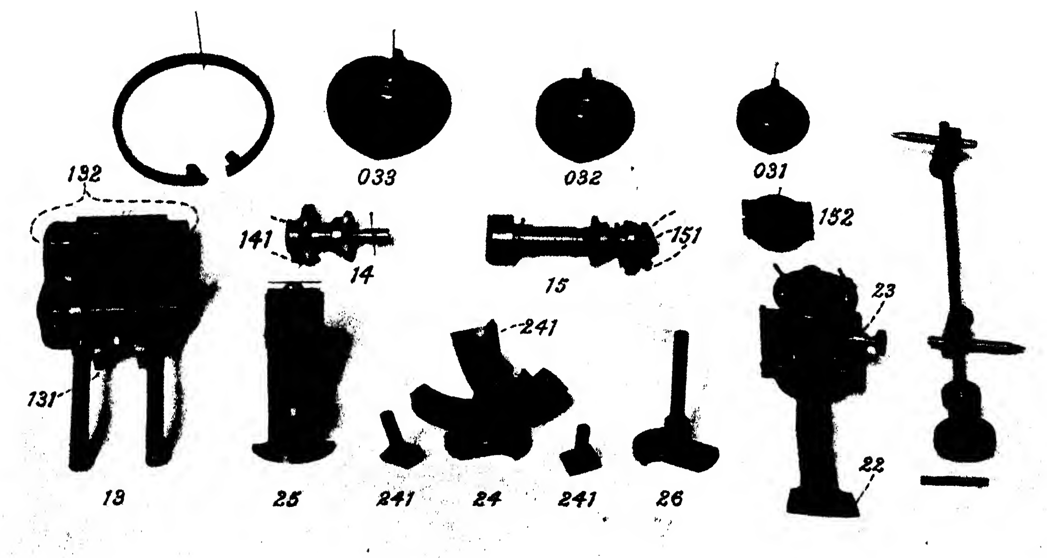


Fig. *F*. Set of small interchangeable parts for instrument (for description see text)

(1) The Aperture System

In the section on the theory of the rotation method we have always considered the X-ray beam as a linear ray impinging on a crystal of infinitesimal dimensions. This, of course, is never the case. The X-rays always diverge from an anticathode spot which is never a geometrical point, and all that an aperture system can do is to limit the cross-section of the beam and its angular divergence. The crystal also has dimensions comparable with those of the apparatus as a whole. Obviously the greater the dimensions of the apparatus with the same aperture width and crystal, or the smaller the aperture width and crystal with the same apparatus, the closer the approximation to ideal conditions. But both of these involve loss of intensity and consequently longer exposure, and the problem is that of finding optimum conditions for accuracy compatible with practical exigencies. To see the effect

of the departure from ideal conditions we may first of all consider the case of an infinitesimal crystal struck by a linear ray which is not perpendicular to but which makes an angle $\frac{\pi}{2} + \sigma$ with the axis of rotation, where σ is the small angle. It can be shown that the effect of this is that the spot is drawn out into a line in the direction of the ξ constant curves* of the rotation diagram and that $\delta\zeta = \sigma$. Similarly if the ray be turned through an angle τ in the equatorial plane, the spot becomes a line parallel to the ζ constant lines with

$$\delta\xi = \tau \left(1 - \frac{\rho^4}{4\xi^2}\right)^{\frac{1}{2}}.$$

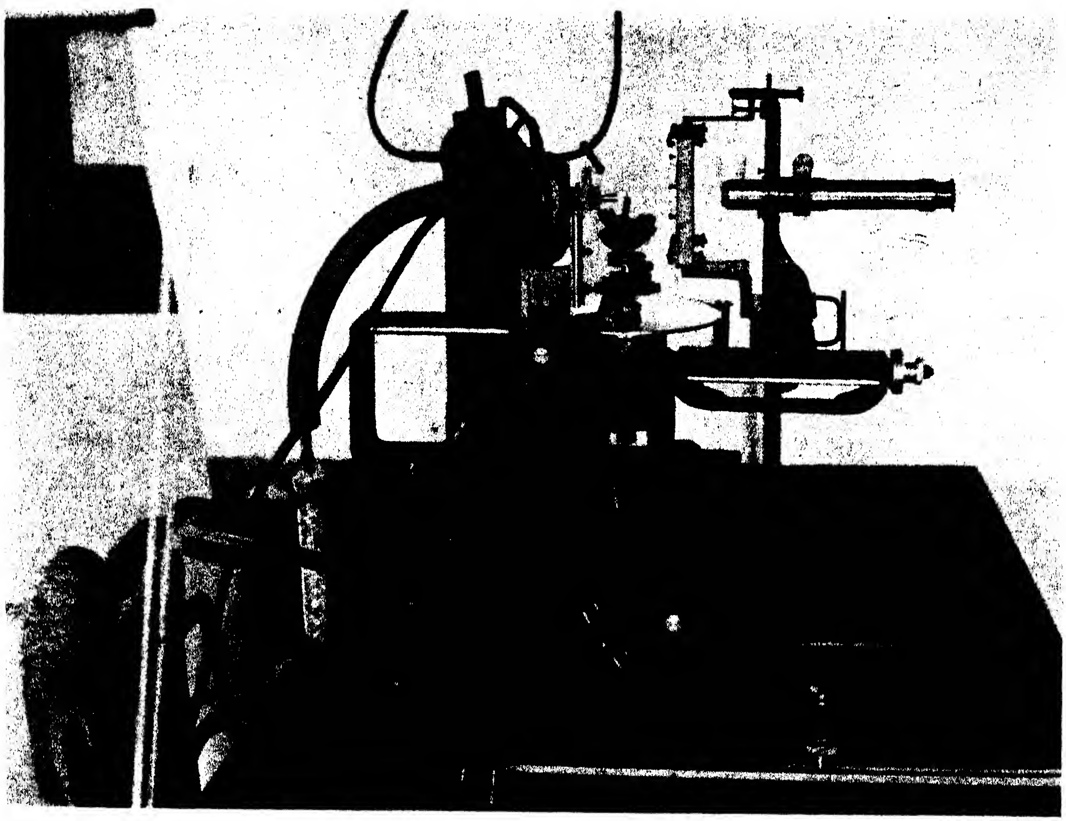


Fig. *G*. The instrument as used with Shearer type X-ray tube. It is mounted on rails, permitting its replacement after adjustment. All the lead shielding is between the tube window and the first aperture, giving complete safety and permitting easy access (see following parts)

If the aperture is circular the limiting condition

$$\sigma^2 + \tau^2 = u^2$$

becomes on the plate

$$\left(1 - \frac{\rho^4}{4\xi^2}\right) d\xi^2 + d\zeta^2 = u^2,$$

which shows that the spot is an ellipse in the $\xi\zeta$ plane, *i.e.* on the rotation diagram, and further the ellipse is nearly a circle when ξ is small. On either a plane plate or a cylindrical

* See Part I, this *Journal*, 4 (June, 1927), No. 9.

film the spot will still be an ellipse but its principal axis will, in general, no longer be parallel either to the equatorial or to the principal lines, and, except in the immediate neighbourhood of the centre, its shape will not be approximately circular (see Fig. 4). Any other shape of aperture will fairly obviously give rise to spots on the plane whose projections on the rotation diagram will be very similar in shape to the aperture itself.

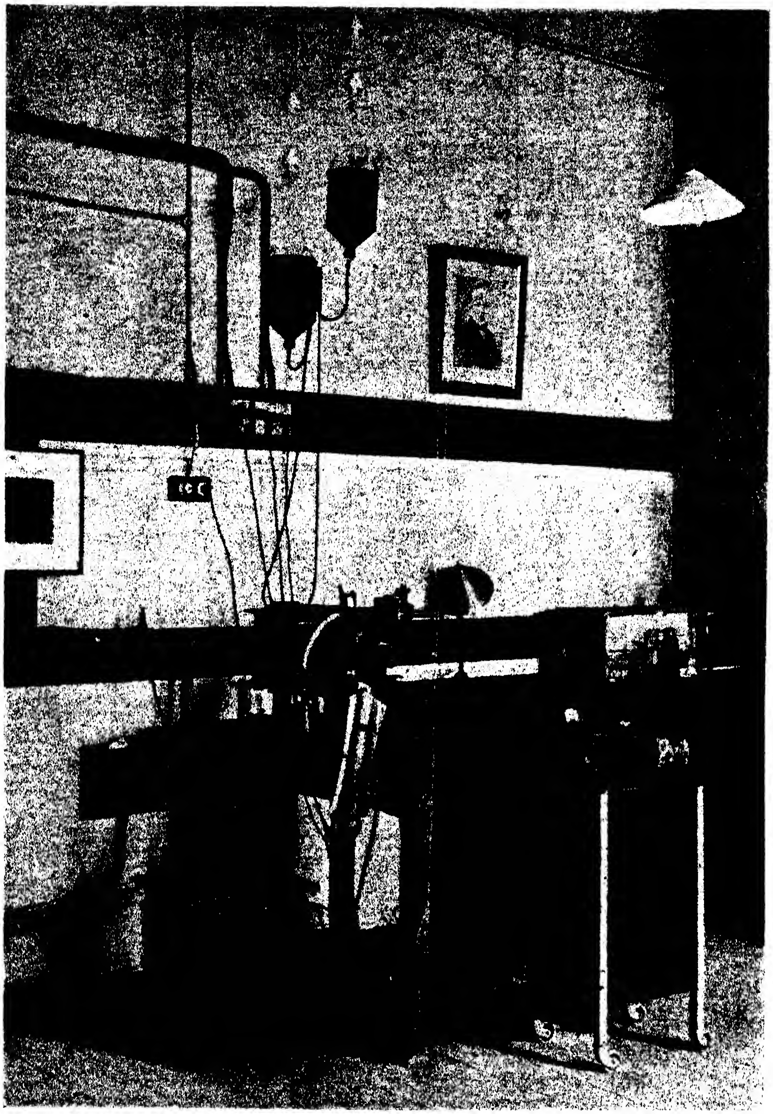


Fig. *H*. Complete X-ray photographic unit with Shearer tube, diffusion and Hyvac backing pumps, Watson transformer and controls. The two vessels seen suspended at the top are an insulated cooling system for the cathode of the tube

So far we have considered the crystal reduced to a point and the beam in the form of a cone converging on it. This is still an ideal case. Actually the size of the crystal is of the same order as that of the apertures. The most general systems of apertures and crystal are shown in Fig. 2 (*a*) and (*b*). The four essential elements are the focal spot of the X-ray tube F, the two diaphragms A_1, A_2, and the crystal C. We may consider that in all cases the

total area of the aperture is so small that it is entirely covered by the extent of the focal spot, so that the rays may be considered to arise all over the area of the first aperture A_1.

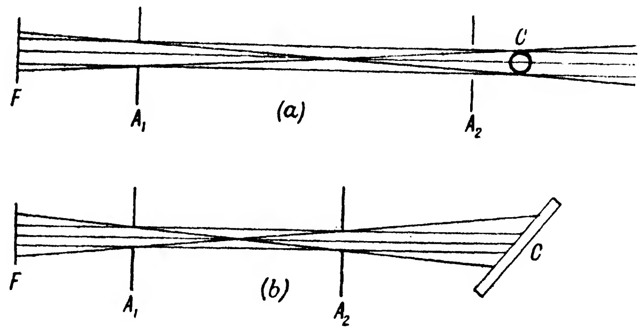


Fig. 2

Two main cases now arise; the crystal may receive all the rays that fall on it from A_1 (Fig. 2 (*a*)) or some of these may be cut off by the second aperture A_2 (Fig. 2 (*b*)).

(*To be continued*)

DUPLEXING THE SUBMARINE CABLE.

By D. C. GALL.

[*MS. received, 24th April*, 1928.]

ABSTRACT. In duplexing practice a balanced "bridge" is formed by an arrangement of two ratio arms and an artificial cable. By the use of a device known as the Adjustment Restorer impedance may be introduced into the bridge circuit by means of which the balance can be restored at any frequency, and the balance errors at the different frequencies determined. For satisfactory working the artificial cable must be adjusted so that the balance errors are kept within the limits beyond which mutilation of the incoming signals occurs. Means of effecting this adjustment are described.

The practice of duplexing submarine cables to enable simultaneous messages to be sent from each end dates from about 1874, and has become almost universal, so that there can be hardly a submarine cable of any importance which is not duplexed at the present time, with the exception of the new loaded cables.

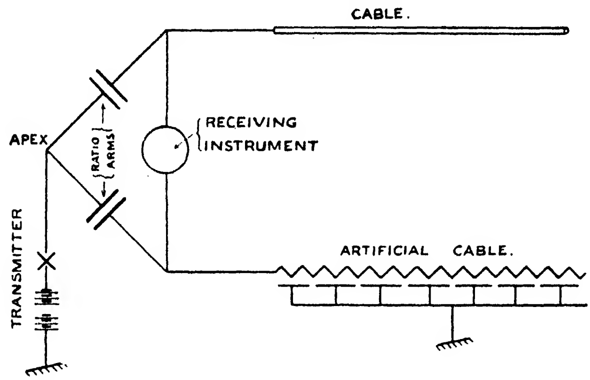
The principle of duplexing is to form the end of the cable into a balanced "bridge" by the use of two ratio arms and an artificial cable. The receiving instrument is then across the balanced point of the bridge, and should therefore be unaffected by currents entering at the apex point or opposite corners of the bridge, but susceptible to currents entering from the cable, that is, from the distant station (see Fig. 1).

The currents entering the apex of the bridge are the varying impulses which compose the telegraphic signals, in the form of dots, dashes or reversals of varying length or polarity according to the type of telegraphic signal employed. The duplex bridge circuit must therefore be balanced for varying currents, and is consequently an impedance bridge balanced for a wide range of frequencies.

Although duplexed cables have been working for over fifty years, there is still very little data available with regard to the impedance of the cable or the actual degree of balance necessary or obtainable for working conditions of the cable. The advent of the "magnifier" in its varying forms to increase the sensitivity of the receiving instrument brought with it

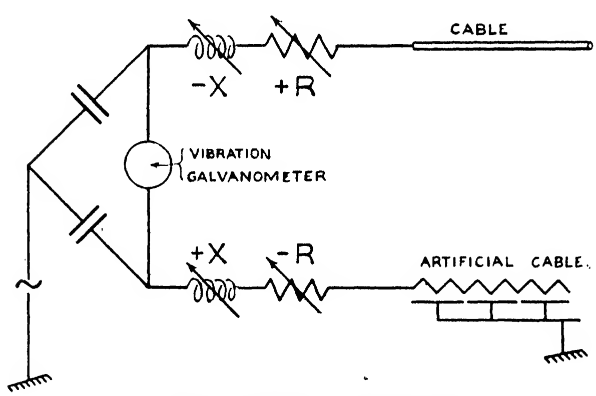
the need for considerable improvement in the duplex balances then existing upon the cables, but a systematic investigation into what is really required to constitute a duplex balance seems to have been left to comparatively recent years.

From the telegraphic point of view, the artificial line which balances the cable must be so adjusted that transmission can take place at the highest desired speeds, without disturbing the receiving instruments sufficiently to mutilate the minute signals received from the distant station. Deficiency in balance is easy enough to observe, but the indications give no guidance as to the remedy. It was desirable, therefore, to develop some definite



DUPLEX BRIDGE.

Fig. 1



ADJUSTMENT RESTORER CIRCUIT.

Fig. 2

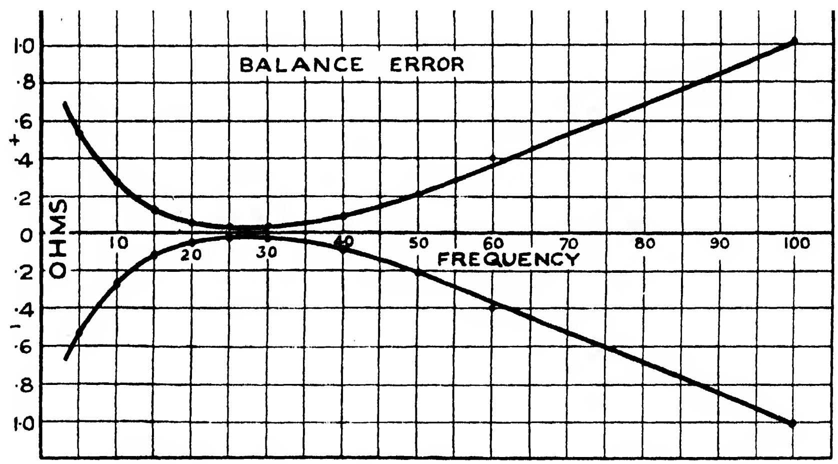
method of measuring the condition of the balance, and from such measurements, if possible, to devise means of improvement. This has been done by the means described in Patent No. 262991 and others of later dates.

The method employed is to send alternating current of various frequencies into the apex point of the bridge, instead of the interrupted direct current used for transmission. A perfect duplex balance would exist if the balance remained perfect at all frequencies. A perfect balance, however, does not exist, and a device is used to introduce impedance into the bridge circuit by means of which balance is restored. The impedance introduced by this device gives the balance errors at the different frequencies. This device is called the Adjustment Restorer. It is thus possible to construct curves of the actual balance error at all frequencies.

The simplest type of circuit which is used for these measurements is shown in Fig. 2. During measurement a vibration galvanometer is used in place of the usual receiving instrument, and an alternator in place of the transmitting key. The balance errors are read directly as a positive or negative resistance error or reactance error; that is to say, the artificial cable has too much resistance or reactance if the error is positive.

To those familiar with the usual receiving instruments of the cable it will be obvious that their sensitivity will vary at different frequencies, so that the perfection of the balance is much more critical at some frequencies than at others. It is advisable, therefore, to have some data to which the error curves can be referred, since much larger errors can be tolerated at some frequencies than at others.

This is easily carried out by using the alternator with the normal receiving instruments, and after balancing by means of the Adjustment Restorer, disturbing the balance by the maximum permissible amount, as indicated by the normal receiving instruments, beyond which mutilation of incoming signals would take place. The amount of impedance necessary



TOLERANCE CURVES

Fig. 3

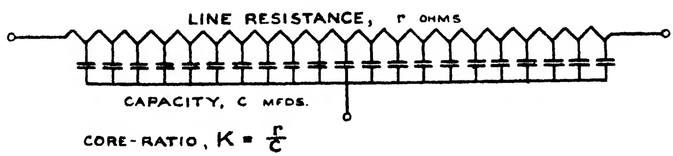
to produce this disturbance is then the maximum permissible balance error at that frequency. A curve of maximum permissible errors at all frequencies can be constructed. This is known as the tolerance curve. It follows, therefore, that if the balance is to be such that no disturbance takes place when transmitting, the balance error curves must lie inside the tolerance curve.

A typical tolerance curve is shown in Fig. 3. It will be seen that the balance must be very good at 25 cycles, but at lower and particularly at higher frequencies quite large errors may exist. The shape of the tolerance curve depends upon many things, mechanical and electrical in most cases. These include the "shaping circuit" which is used to shape the incoming signal, the impedance of the bridge circuit and the mechanical periods of the various moving parts. The measurement of the tolerance curve sometimes reveals "saddle points" whose presence is an unsuspected difficulty in the way of balancing; for example, a sudden approach to the zero line at a high frequency. In such a case this can be eliminated by adjustment to the receiving circuit, without affecting the reception of the signals.

The artificial cable consists of a network of resistances in series and condensers in parallel, and adjustments to the balance are made by varying the meshes of the network at different points, or by introducing other impedance devices at various distances from the beginning.

The simple theoretical diagram of the artificial cable is given in Fig. 4. If such an artificial cable balanced the real cable perfectly, and an alteration of one ohm were then made in the line resistance at any distance along the line, the balance error curves at all frequencies which would be produced at the balance point of the bridge would be those given in Fig. 5. The theory of the error curves has been described elsewhere*.

These curves form the basis of an understanding of the balance errors. The curves shown in Fig. 5 are known as single error curves, since they are due to an error at one point only. The actual balance errors measured in practice are made up of a number of single error curves superimposed. Their form becomes very complicated, owing to the varying period and magnitude of each curve. Simple rules for their elimination have been devised, however.



ARTIFICIAL CABLE.

Fig. 4

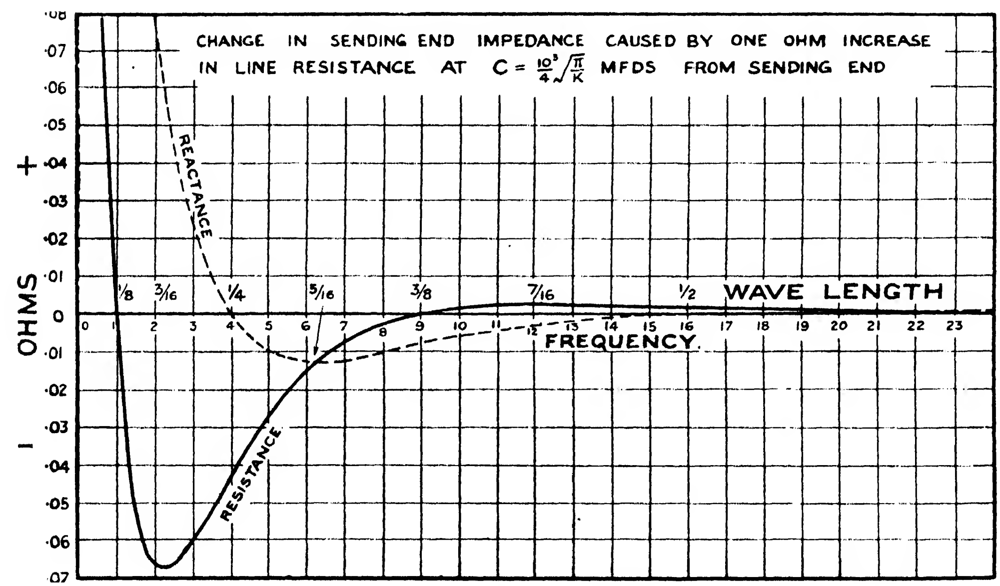


Fig. 5

In order to perfect the duplex balance the error curves must not lie outside the tolerance curves. A typical error curve is shown in Fig. 6. The full line is the resistance error, the dotted line the reactance error. Balance error curves of an actual cable are shown in Fig. 7. These conditions gave a good working balance, although it will be seen that the errors are considerable except round the 25 cycle point, which was the critical frequency for the speed at which the transmission took place. The errors expressed as a percentage of the cable impedance lie within 0·1 per cent. from 6 to 30 cycles. From these measurements it is evident that there is room for considerable improvement in the balance. A perfect balance would exist if resistance error curves were reduced to a straight line and the reactance error

* *Perfecting the duplex balance of the submarine cable,* by D. C. Gall. H. Tinsley & Co., Werndee Hall, South Norwood, London, S.E. 25.

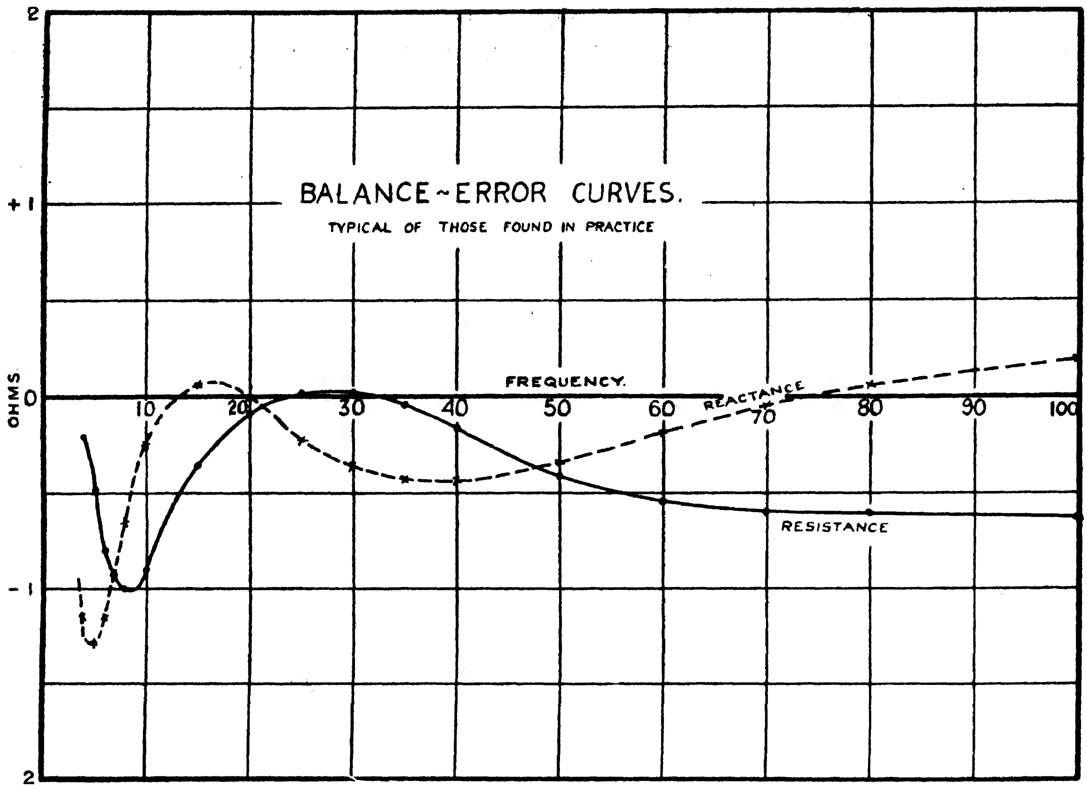

BALANCE ~ ERROR CURVES.
TYPICAL OF THOSE FOUND IN PRACTICE
FREQUENCY.
REACTANCE
RESISTANCE
OHMS
+1
0
-1
2
10
20
30
40
50
60
70
80
90
100

Fig. 6

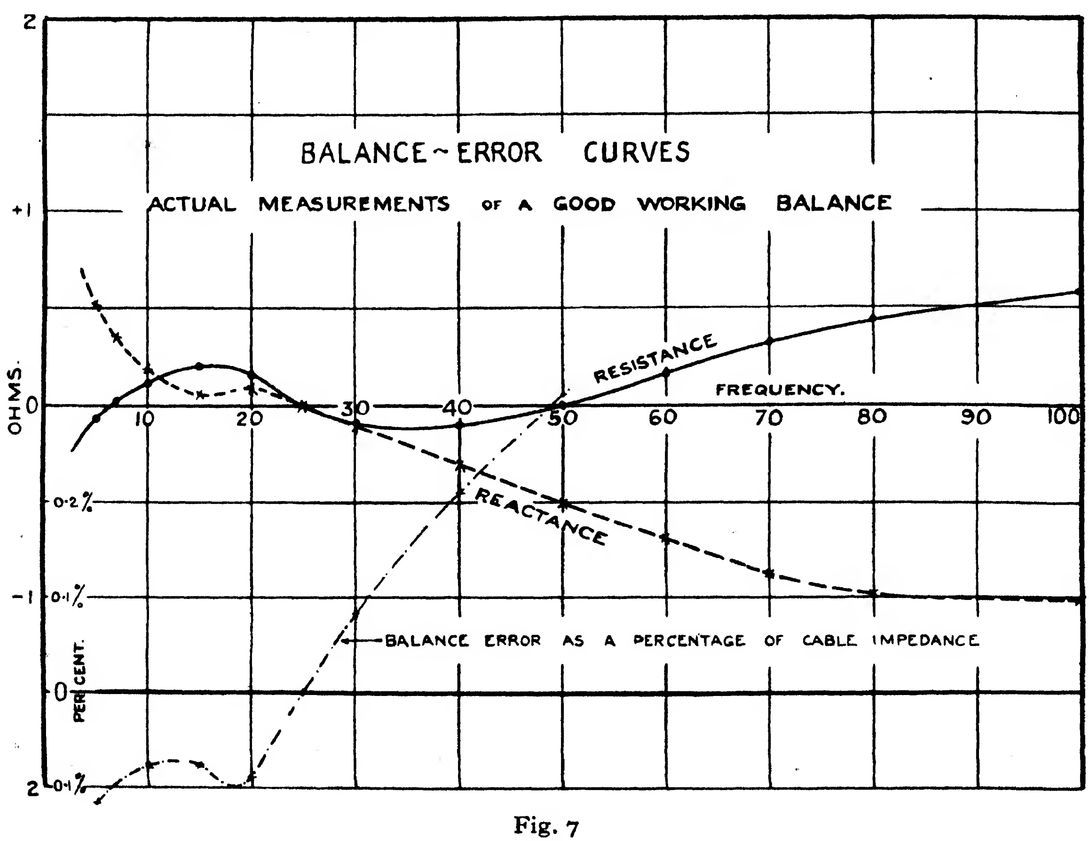

BALANCE ~ ERROR CURVES
ACTUAL MEASUREMENTS OF A GOOD WORKING BALANCE
RESISTANCE
FREQUENCY.
REACTANCE
BALANCE ERROR AS A PERCENTAGE OF CABLE IMPEDANCE
OHMS.
PER CENT.
+1
0
0·2%
-1
0·1%
0
2
0·1%
10
20
30
40
50
60
70
80
90
100

Fig. 7

to zero. The resistance error may have any value so long as it is constant, as a single series resistance in front of the cable or artificial line will correct such an error.

The process is as follows. From Fig. 5 it will be seen that the first bend of any magnitude departs from zero at the $\frac{3}{8}$ wave-length. This $\frac{3}{8}$ wave-length is the point along the cable where the current is lagging $\frac{3}{8}$ of a circle (in time) behind the current at the sending end of the cable. It is convenient to know this position in microfarads from the sending end, and this is given by the simple formula

$$C = 2 \times 10^3 \sqrt{\frac{\pi}{f\kappa}} \times \frac{3}{8} \text{ mfds.},$$

where κ is the core ratio of the cable in ohms per mfd. and f is the frequency. The wave-length position will vary, therefore, with frequency, so that for every frequency there is a certain point along the cable corresponding to the $\frac{3}{8}$ wave-length. (A curve is constructed for convenience giving values of C in terms of f.)

If an adjustment is made to the line resistance at this point the sending end impedance will be changed in such a way that an "error" will be produced following the curves given in Fig. 5. That is to say, there will be no practical change for higher frequencies, but the resistance error will begin from that frequency and increase as the frequency is decreased. Thus the resistance error curve can be bent in any desired direction at any frequency by making an adjustment to the line resistance at the $\frac{3}{8}$ wave-length corresponding to that frequency. This is the method used to straighten the resistance error curve.

The error curve is bent this way and that, in short pieces, until straight at successively lower frequencies. For example, to correct a downward bend at 50 cycles in Fig. 7 a decrease in the line resistance would be made at

$$C = 2 \times 10^3 \sqrt{\frac{\pi}{50\kappa}} \times \frac{3}{8} \text{ mfds.}$$

This adjustment might be such as to straighten the curve down to 40 cycles, at which point the curvature would be in the opposite direction, so that an increase in the line resistance at

$$C = 2 \times 10^3 \sqrt{\frac{\pi}{40\kappa}} \times \frac{3}{8} \text{ mfds.}$$

would be required to correct this, and so on until the resistance error curve lies within the limits set by the tolerance curve. The results of such adjustment are shown in Fig. 8.

In the meantime the reactance errors will have been considerably altered. These errors are now dealt with as a separate problem; the method being to introduce a purely reactive network in front of the cable or artificial cable to balance out these reactance errors over the desired frequency range. The values for the meshes of the reactive network can be determined by substituting the reactance error, after straightening the resistance curve at, say, 10, 15, 20, 25, 30 and 40 cycles, in the equation of the network.

So far as data are available it would seem that the present artificial cables in their initial conditions are very poor duplicates of the actual cable. Very large adjustments are required to produce a balance over quite a small frequency range, and the magnitude of these adjustments must, from the form of the error curves so produced, limit the possible perfecting of balance to a narrow frequency band. It should be relatively easy to modify the construction of the artificial cable to balance the real cable more nearly without such drastic adjustments as are now common. For telegraphic purposes elimination of the error curves over about three octaves should be quite sufficient for an excellent working balance.

Not all balance errors are due to the difference in impedance between the artificial and the real cable. The ratio arms used to form the bridge may have errors in balance varying

with frequency. This is found to be the case, and errors of considerable magnitude have been found in this part of the circuit. The measurement is made by substituting a special pair of non-inductive ratios in place of the cable and artificial cable and balancing at different frequencies by means of the adjustment restorer circuit. Balance errors are caused also by the indeterminate position of the "earth" corner of the bridge; the cable earth being distributed while the artificial cable earth and battery earth are more closely defined.

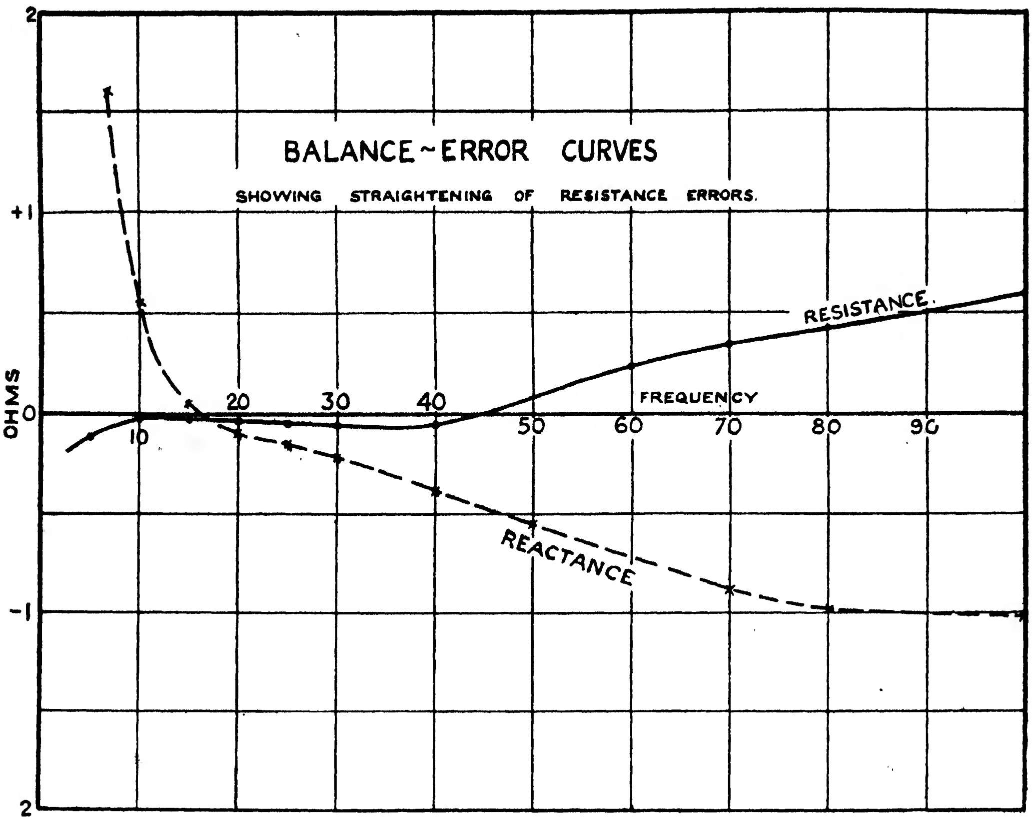


Fig. 8

Balance errors from any source, however, can be eliminated by adjustment to the artificial cable in the way described above.

The advisability of so arranging the bridge that the frequency errors of balance will be reduced to a minimum naturally follows. It is for this reason that the "apex resistance" inserted between the two ratio arms and the apex point can be such an unsatisfactory type of adjustment in practice, the inequality so introduced giving a new set of error curves varying with every setting of the apex resistance.

The Adjustment Restorer and auxiliary apparatus are made by Messrs H. Tinsley & Co., Werndee Hall, South Norwood, London, S.E. 25.

NEW INSTRUMENT

A NON-INDUCTIVE POTENTIAL DIVIDER OF HIGH PRECISION

At the request of the National Physical Laboratory the instrument described below was constructed by Messrs H. Tinsley and Co., Werndee Hall, South Norwood, London, S.E. 25. It consists of four dials and a slide wire. The total resistance is 1000 ohms and this is subdivided by the dials and slide wire to 0·001 ohms; thus each graduation of the slide wire represents one part in a million of the total resistance. The subdivision is arranged upon the Thomson-Varley principle, and accordingly the first dial consists of eleven 100-ohm coils. The switch has two arms which make contact with two studs.

The connexions are such that the whole of the coils of the second dial shunt the two coils of the first dial upon which the switch arms rest. The shunting effect of the second dial reduces the resistance of the two coils on the first dial to the value of one. Thus the eleven 100-ohm coils are reduced in effect to ten, making the total of 1000 ohms. The second

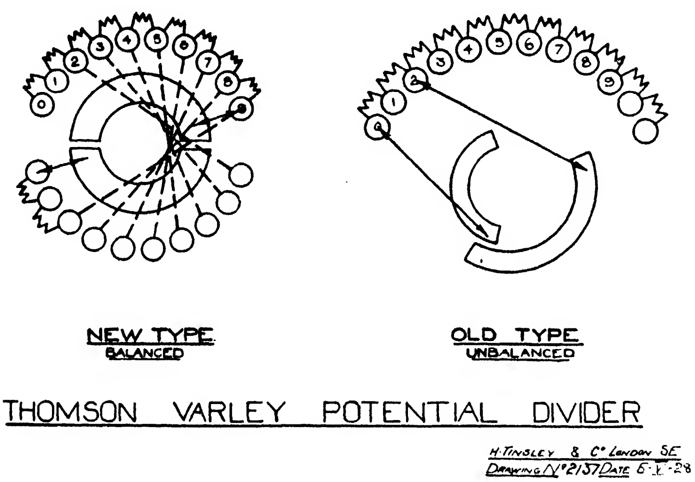


Fig. 1

dial, too, consists of eleven coils, the resistance of each coil being 20 ohms. Two coils in turn are shunted by the third dial, and so on to the fourth. The slide wire shunts two coils of the fourth dial. The third dial has eleven coils of 4 ohms each. The fourth dial eleven coils of 0·8 ohms each and the slide wire has a total resistance of 1·6 ohms. The potential point is the slider of the slide wire and this is taken out to a terminal.

In order to reduce the chance of contact trouble use has been made of the recently developed "Dual contact" type of switch. The design of this form of contact is upon geometric principles, and the results have been very satisfactory.

A perfectly balanced dial with 20 studs reading from 0–9 on each side has been employed. By cross connecting and putting 9 coils on one side and 2 coils on the other the requisite "vernier" connexions can be obtained. This dial arrangement is believed to be novel. It has the advantage of doing away with the difficulty of making a double travelling contact arm on one side of the centre only. Fig. 1 will make the new and the old arrangement clear. Fig. 2 gives the connexions.

All the coils in the potential divider are non-inductively wound according to the special method described in this *Journal**. The resistance range of this instrument is very favour-

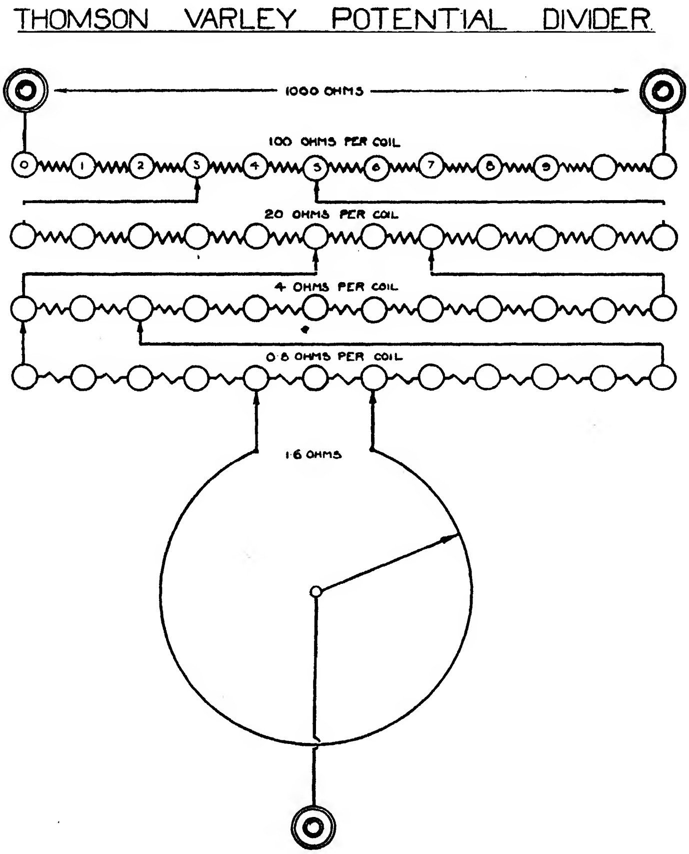


Fig. 2

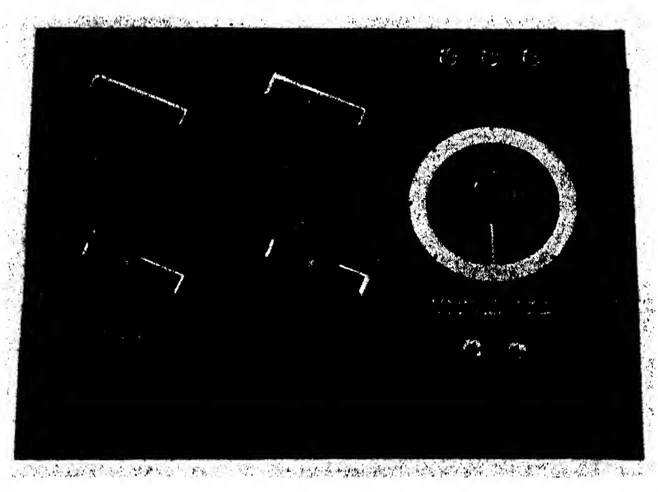


Fig. 3

able for good non-inductive results. An illustration of the instrument is given in Fig. 3. The additional terminals are provided to give separate current and potential connexions.

* See "Non-Inductive Coils and Resistance Boxes." By D. C. Gall, 5 (1928) 222.

LABORATORY AND WORKSHOP NOTES

APPARATUS FOR SAMPLING THE GASES OF SEALED TINS

By C. H. F. FULLER, B.Sc., A.I.C.

C is a glass tube of 7 mm. internal diameter, narrowing to 2·5 mm. and provided with a side tube of 2·5 mm. capillary bore tubing. Sliding easily inside this is a steel needle *A* about 14 cm. long, tapered at the lower end to fit the tapering of the glass tube. A rubber cap *B* makes an airtight joint between the needle and the glass tube but allows the needle to be moved vertically in the tube to a distance of about ½ cm. The rubber pad *D* makes an airtight joint with the tin to be tested.

In use, the capillary tube is attached to an Orsat gas analysis apparatus and the tin to be tested is pressed up against the pad *D*. The tin is then punctured by pressing on the needle *A* and then releasing. Gas can then be drawn into the Orsat apparatus and analysed.

This gas sampling apparatus has the advantage of a very small volume of contained air and of being readily constructed in the laboratory workshop. The cap *B* is similar to those listed in chemical catalogues for covering serum bottles, and the pad *D* is made from a larger size of the same article.

The apparatus has been in use in the laboratories of Messrs J. Lyons & Co., Ltd., for some time, and they have kindly given the writer permission to publish this description.

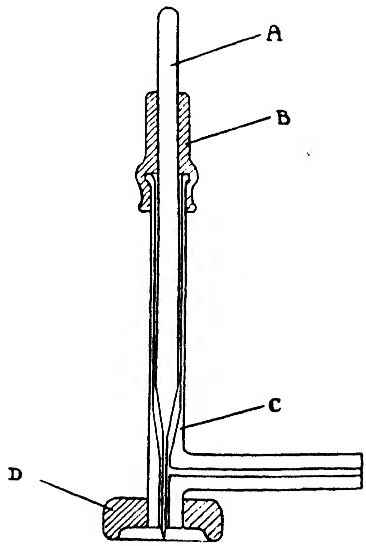


Fig. 1

DEVICE FOR MAKING SPLIT CLOCK GLASSES. By W. PRESTON

In the exact assay of copper by electrolysis it is necessary to cover the beaker, during deposition, with a split clock glass, to prevent loss by spraying, more particularly when

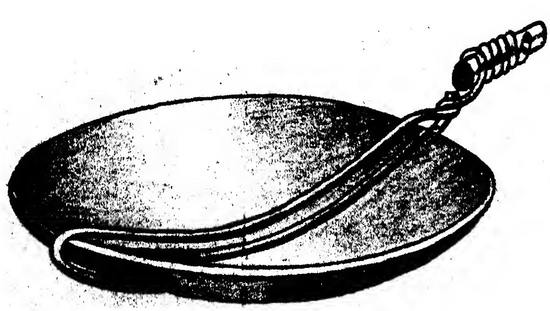


Fig. 1

using concentrated solutions and high current densities. The following is a little device for making these split clock glasses which gives excellent results. Procure about 18 in. of soft copper wire about 14 S.W.G. and shape this at the middle to surround the clock

glass across the centre, twisting the wire to make the necessary clip. The surplus wire is wrapped round a piece of copper rod 1 in. × $\frac{3}{8}$ in. dia. If the clip is made slightly wider than the clock glass this will facilitate matters when making a quantity, as a new glass can then be readily fixed. The knob of the clip is heated in a good bunsen flame for about a minute or until the heat has conducted along the clip; and the whole is immediately plunged into cold water. The glass will crack along the place of the clip, and if not quite straight, which depends on how carefully the clip is fixed on the glass, the two halves are a perfect fit and only require the holes making for the electrodes to pass through, which may be done with a small round file moistened with turpentine containing camphor.

ACCURATE GRINDING OF THE PROFILES OF SMALL FORM CUTTERS

We have already mentioned in these notes the possibility of using the Engraving Machine for the economical production of small batches of components from sheet material where the quantities involved would not justify the cost of press tools. The Engraving Machine can be used also for the accurate grinding of small form cutters, working from an enlarged template, say 10 times the scale of the profile to be ground. The illustration shows the machine, diagrammatically in plan, set up for work of this class.

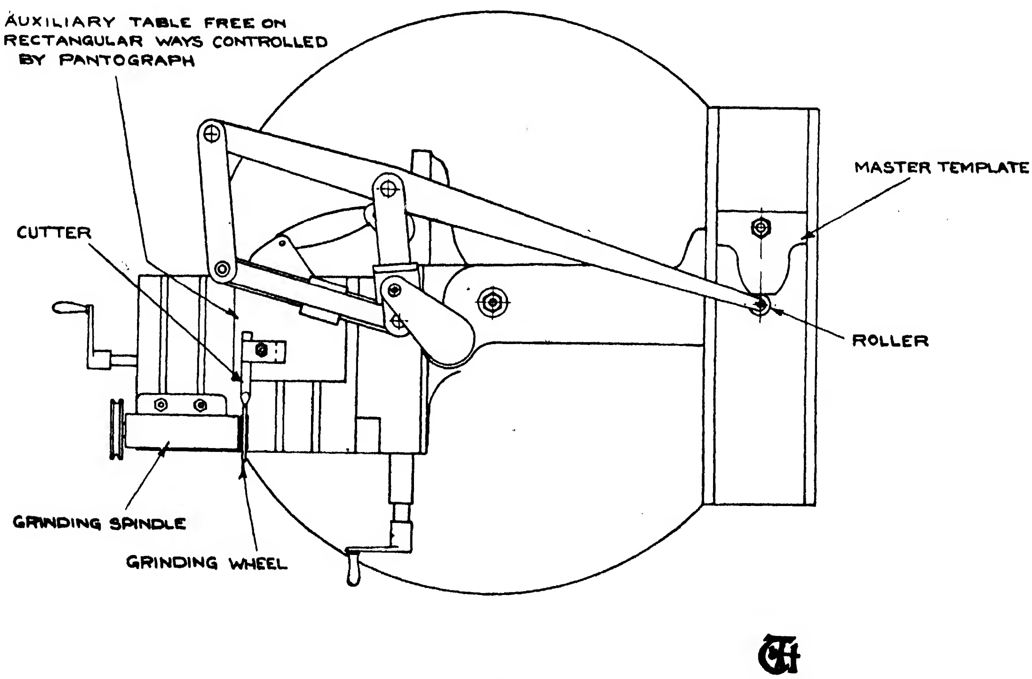


Fig. 1

The grinding wheel is carried on a spindle independently mounted on the table of the machine, while the cutter to be ground is carried on an auxiliary table free to roll on balls contained in rectangular V-grooves under the control of the pantograph. The arrangement of ways permits this auxiliary table to move freely without rotation in all directions; a special plug, which takes the place of the engraving machine cutter spindle quill and engages with a socket in the auxiliary table, causing it to follow the motion of the panto-

graph. As the table is constrained against rotation, every point on it will execute the same motion, corresponding to the path followed by the style.

Thus by truing the section of the periphery of the grinding wheel to a radius proportionate to that of the roller, the movement of the wheel with respect to the job will reproduce that of the roller around the template, and the cutter will be accurately ground to the desired profile.

THE TAYLOR-HOBSON RESEARCH LABORATORY,
LEICESTER.

CORRESPONDENCE

DEVICE FOR CONTROLLING THE HAUGHTON-HANSON THERMOSTAT

The device described by Mr J. D. Grogan in his paper in the July issue of this *Journal* is of great value in connexion with the annealing of metallic specimens in order to attain equilibrium condition. In many cases this can be done much more readily by cooling the specimen very slowly through a transformation than by heating at a temperature a few degrees below the transformation. Dr Hanson and the writer tried many methods for doing this (most of which are described in their papers referred to by Mr Grogan), and finally obtained the most satisfactory results by immersing the bulb *B* of Fig. 1 in a thermos flask containing hot water. The difficulty of renewing the hot water when it became too cold, with the consequent disturbance of the temperature was, however, a serious drawback. Amongst other methods they experimented with an electrolytic cell and stated that "a number of difficulties were encountered mainly due to the polarisation of the cell, but the authors are of the opinion that the method could be made to give satisfactory results."

Mr Grogan was unaware of this previous work when he started experimenting on the subject, and he is to be congratulated on having developed a very useful adjunct to the thermostat.

J. L. HAUGHTON.

THE NATIONAL PHYSICAL LABORATORY,
TEDDINGTON.

THE STRAIGHT LINE RHEOSTAT

In your issue of last month Mr C. L. Lyons describes what he calls "a straight line rheostat" and he appears to think that the system is novel. But it is exactly the well known old Wheatstone rheostat (*Bakerian Lecture*, 1843), of which Lord Kelvin brought out an improved form described in his 1887 Patent. In the "3 E" type the improvements at the maximum and minimum positions are clearly advantageous.

ALBERT CAMPBELL.

CULMORA, GIRTON ROAD,
CAMBRIDGE.

RECENT RESEARCHES AT THE NATIONAL PHYSICAL LABORATORY

(*Continued from p.* 236.)

METROLOGY DEPARTMENT

The National Physical Laboratory Report for the Year 1927. Pp. vi + 264. London: H.M. Stationery Office. Price 7*s*. 6*d*. net.

Invar Standard of Length. The bar was artificially aged by the makers about June 1924, and from the curve of growth of invar prepared by Dr Guillaume it would be expected that an ordinary invar bar would increase in length during the period, between 11 months and 40 months, after the ageing process at a rate of 1·8 parts in a million per annum. This bar, however, was made by the Société Génevoise in special invar, and was expected to be practically free from the secular change which is inherent in ordinary invar. Although this standard is not truly stable, it is better than ordinary invar. Moreover, there is evidence indicating that most of the increase in length occurred during the earlier months, and it is estimated that the present rate of growth is not likely to exceed 0·8 parts in a million per annum.

Comparative Measurements of Block Gauges by the Interference and Mechanical Methods. A table showing comparative measurements of certain 4-inch block gauges by interference and mechanical methods was published in the Report for 1926, p. 147. The interference method there referred to is that by which two optically flat glass plates are brought into wringing contact with the surfaces of a gauge to form a Fabry-Pérot étalon, the exposed parts of the glass surfaces in contact with the gauge being rendered partially reflecting by light silver deposits. It was observed from the table mentioned above that, on the average, the value of the length of a 4-inch gauge derived from interference measurements, after applying the necessary corrections, was smaller than the mechanical value by about 0·000,002 to 0·000,003 inch.

Further comparisons during 1927 have shown that a similar discrepancy is observed between the two methods for gauges down to half-an-inch in length. The fact that the difference is not proportional to length eliminates doubt concerning the measurement of temperature, the values of wave-lengths in terms of the metre, the value of the conversion factor between the metre and the yard, or the mechanical method by which the length of a gauge is determined in terms of the yard. It is therefore concluded that the optical method described above is liable to a more or less constant experimental error.

Measurement of Fine Quartz Suspension Fibres. The measurement of quartz fibres is of some importance to instrument makers in order that suspensions of known torsional stiffness may be used. Such a measurement presents considerable difficulties if attempted by any ordinary means. Thus, weighing the fibre is impossible on account of its very small mass, and any method involving the use of a microscope is quite unreliable, as the diameter is only of the same order as the wave-length of visible light, and is thus beyond the limit of resolution.

Two indirect methods of examining fibres have been devised. One of these gives a measurement of the average diameter by stretching the fibres with a known tension and measuring the extension produced. From the known value of Young's modulus the mean diameter can be calculated. The method readily yields an accuracy of 5 per cent. The second method of measurement depends upon the observation of certain diffraction phenomena produced when a quartz fibre is placed in an intense beam of white light. It is found that the phenomena are similar to those produced when a fine slit is illuminated with white light, and that the fibre has an "equivalent slit-width" which is equal to its diameter when that is greater than about 2μ. The equivalent slit-width is calculated by means of the usual formula derived from the theory of the fine slit, and the method involves observing the angular positions of maxima of a certain colour. For diameters less than 2μ this optical method tends to give larger errors as the diameter approaches the dimensions of a wave-length. The optical method provides a rapid means of comparison with a standard fibre which has been mechanically measured by the former method.

Forces between Block Gauges. Two interesting facts may be mentioned regarding the wringing process applied to block gauges when combinations are to be formed. One is that the force necessary to separate a pair of gauges when wrung together with paraffin oil is only about 30 lb. per square inch immediately after wringing, but it increases to about 80 lb. per square inch or higher when an interval of about one hour has elapsed after wringing. The other is that the average decrease in size of a block gauge per surface per wringing was actually about $1{\cdot}6 \times 10^{-8}$ cm., a quantity equivalent in magnitude to the diameter of a molecule as determined from the kinetic theory of

Pivots and Jewels. The larger the radius of curvature of the end of a pivot, other conditions remaining constant, the larger will be the frictional torque between the pivot and its jewel. To reduce friction it is therefore desirable to employ a small radius of curvature. On the other hand, the smaller the radius of curvature, the smaller will be the load which the pivot can support without suffering permanent deformation. The determination of a suitable radius for a given pivot must therefore be a compromise. The radius must be kept small enough to make the friction sufficiently low, but not so small as to render the pivot liable to suffer permanent deformation. This problem has been investigated theoretically. The conditions for avoiding permanent deformation of the pivot have been derived from the results of the loading experiments mentioned in last year's Report and Hertz's investigation on the contact of elastic bodies. A relation has also been developed for determining the frictional torque between a pivot and jewel in terms of the radii of curvature of the two, the elastic constants of the materials from which they are made, the load, and the coefficient of friction. These two relations enable one to calculate radii for both pivot and jewel suitable for any particular purpose.

ENGINEERING DEPARTMENT

Efficiency of Power Transmission by Gears. Tests on gears in which errors have been purposely introduced in (i) the radial alignment of certain teeth, and (ii) the pitch of the teeth, made at a tooth load of 1500 lb. per in. of tooth width and at a speed of 1500 r.p.m. (which corresponds to the transmission of approximately 100 H.P.), have indicated uniformly an efficiency of 99·2 to 99·4 per cent. In almost every case failure of the gears has taken place not by abrasion of the tooth surface, but by fracture of a tooth near the root, and it would appear from the results that the root radius adopted governs the tooth strength in a considerable degree.

Seizing Temperatures of Oils. There seems good reason to suppose that the phenomenon of the seizing of a cylindrical journal and its bearing coincides with the transition from film to boundary lubrication. Hitherto all the available evidence has indicated that the fixed oils have much higher seizing temperatures than mineral oils, as shown by the common method of treating a hot bearing under mineral oil lubrication by the application of castor oil, which usually cures the trouble. This action is ascribed to the different molecular constitution of the mineral and fixed oils. That this explanation is not complete is indicated, however, by determinations of seizing temperatures which have been made on two high-grade mineral oils, and a comparison of the results with the corresponding value for castor oil. The three oils had approximately the same viscosity and density so that their behaviour under conditions of film lubrication should be approximately the same. On testing them for temperature of minimum friction and seizing temperature it was found that No. 2 mineral oil had a seizing temperature of 224° C., or 86° C. higher than that of castor oil under the same conditions of load and speed. In the case of No. 1 mineral oil the seizing temperature was 45° C. lower than that of castor oil. The chemical constitution of the No. 2 oil is being carefully studied.

New Alloys for High Temperatures. The work on new alloys suitable for use at high temperatures has been continued. Tensile and creep tests have been carried out on the following materials made in the Metallurgy Department:

(i) Chill cast nickel-chromium alloys containing up to 60 per cent. chromium.
(ii) Roller bars of nickel-chromium alloys containing up to 40 per cent. chromium.
(iii) Ternary alloys of nickel, chromium and iron, of various compositions.

Tests carried out at high temperatures on the alloys containing 30 and 40 per cent. of chromium gave results slightly superior to those on alloys containing only 20 per cent. of chromium. In the creep tests at 800° C. failure occurred mainly by cracking, and in order to obtain satisfactory comparison between new and existing alloys, tests have also been made at 650° C. Cast nickel-

chromium alloys of the proportions 25 : 25 : 50 have so far given the best performance under prolonged loading at 800° C.

Rust Prevention. The experiments on crude lanoline as a protection for steel surfaces against rusting have been concluded and the final report is being prepared for publication. This report includes a specification for the crude lanoline and for suitable mixtures for liquid preparations. The later tests have included experiments on colouring the grease or solution by means of aniline dyes soluble in oil, and on hardening the grease film by additions of wax. A number of test-pieces coated with lanoline mixtures are now stored in various Government stores to determine the life of the coatings under such conditions of storage and subject to periodical handling.

The general result of the tests is to show that crude lanoline, which is at present largely a waste product in the woollen industry, is as efficient a protection against rust as the best imported petroleum grease and is much less expensive. It may be used either as a grease or deposited from various solvents. The solvents recommended are white spirit (British Standard Specification 245, 1926) and solvent naphtha free from benzol (British Standard Specification F. 17). These solvents do not give off fumes dangerous to health, and with ordinary precautions are not liable to cause explosions. The recommended solutions are made up by mixing lanoline and the solvent in the following proportions, preferably at a temperature of 60° to 70° C.

Mixture 1. 7·6 lb. crude lanoline, and one gallon of white spirit.

Mixture 2. 8·3 lb. crude lanoline, and one gallon of solvent naphtha.

Work on Aluminium. As reported previously, careful density determinations, made before and after test, showed that no change in density occurred in single crystals of aluminium subjected to safe or unsafe ranges of alternating direct stresses. The fatigue limit for such single crystals was approximately 1·5 tons per sq. in. These experiments have now been repeated on aluminium in the usual finely divided state. The limiting range of stress for the polycrystalline material was found to be 2·2 tons per sq. in. This increased value may be ascribed to one or both of two causes, viz., (*a*) higher average effect of varying orientation of the crystals in the aggregate, and (*b*) the "strengthening" effect of the boundaries due to inhibition of slip caused by change of orientation of neighbouring crystals. In connexion with (*a*) it is possible that, owing to the initial rolling of the rod, a fibre structure (preferred orientation) has been set up and has persisted throughout the subsequent annealing processes. This possibility is being investigated, using radiographic methods. The density tests with this finely divided material were positive and showed clearly that the effect of the alternating stresses was to produce a decrease in density, the amount of which varied between 0·037 and 0·100 per cent. Thus the results of the work on the monocrystalline and polycrystalline states, as well as a consideration of the results of other workers, suggest that a decrease in the density of a metallic specimen due to cold working marks an effect which is confined to the neighbourhood of crystal boundaries or is due to the presence of such boundaries; where no such boundaries are present, as in the single crystal experiments, changes of density do not occur.

Miscellaneous. Interesting results are summarized on wind pressure and vibration in buildings and bridges, on road surfaces, and on the stability of the Tower of London.

TANK DEPARTMENT

Tests for Firms. The greatest improvement obtained by the tank during the year, by modification of firms' original proposals, has been a reduction of hull resistance of 13 to 19 per cent. over the range of speed tested, while in two other cases screw propeller efficiency has been increased by more than 12 per cent. In addition to these, in three cases the shape of the hull form has been determined by the firm following suggestions made by the Tank, and in eight other cases the form of the hull has been determined at the Tank to meet the firm's requirements. In tests of propellers, an endeavour is made to reduce the amount of shop work at the Tank by altering the proposed propeller before testing to what is thought a better form, the technical staff of the firm concerned being informed of the reasons for such alterations and of the limitations of the resulting propeller as far as these are then known. In this way the cost of the work is kept within moderate limits, and the resulting propeller is made to connect up the engine and hull correctly.

Aeronautical Work. Three type tests of seaplanes with twin floats and one type test of a flying boat have been made, involving eight models and their modifications. Of these, three have been

made for the Air Ministry and one for a private firm. In all work done for the Air Ministry photographs of the water disturbance have been taken at characteristic speeds. The corresponding number of types tested in 1926 was 6, and 13 in 1925. A comparison between the "porpoising" developed by a model and a full-sized hull when running at different speeds is in hand in conjunction with the Marine and Armament Experimental Establishment at Felixstowe; it is expected that this research will shortly be completed. Time has again not been available to carry out experimental research in the Tank in connexion with the resistance or behaviour of seaplanes or flying boats.

Manœuvring of Ships. The experiments on the effect of fullness of form on rudders of ordinary type behind single-screw vessels have been completed and the results analysed. A paper on this subject was presented by Mr Bottomley to the Institution of Engineers and Shipbuilders in Scotland, and read at Glasgow on February 8th, 1927. The experiments have shown that with the propeller working:

(1) The varying fullness of the hull had very little effect on the rudder forces and ship turning moments.

(2) With constant area of rudder, change in its shape (in all cases when the ship was loaded) had very little effect on the rudder forces and ship turning moments, unless an unusually long rudder was used.

Calculation of Wave Resistance. A second paper on this subject was read by Mr Wigley at the Spring meeting of the Institution of Naval Architects. In this paper details were given of calculations and experiments on models having the same form, length and draught, but having beams in the ratio 1·0, 1·5 and 2·0. These models were tested to see how nearly the wave resistance would vary as the square of the beam, as is demanded by the approximate theory on which the calculations are based.

It was found that as the beam was reduced the discrepancies in shape between the calculated and experimental wave resistance curves diminished, as might be expected, since several of the assumptions made come nearer the truth as beam is reduced. The absolute values, however, tended to differ more as the beam was reduced. The wave resistance in the case of the model results was obtained by deducting from the measured resistance the value of frictional resistance calculated from Froude's friction data, assuming the surface to be a flat plank. The varying differences in wave resistance were attributed to errors in this assessment of the frictional resistance. An increase of 2 per cent. in the frictional resistance in the case of the broadest model would cause agreement between the experimental and calculated curves, while 3 per cent. increase would be needed for the intermediate and 4 per cent. for the narrowest model.

R. T. B.

(*To be continued.*)

REVIEWS

Science for You. By J. G. Crowther. Pp. x + 242. London: George Routledge and Sons, Ltd. Price 5*s*. net.

This volume contains a number of essays in scientific journalism, written in pursuance of the theme that "one of the necessities of the hour is that the public should know more about science," and describing in popular terms some notable researches and theories in pure and applied science.

Many of the articles are very readable, such as, for example, that on earthquakes and meteorological phenomena; and another on electric lamps and the Coolidge tube. These, one would say, serve their purpose admirably, as also the brief biographical note on Sir Isaac Newton. It is much to be regretted that greater use is not made of the biographical peg on which to hang popular accounts of scientific work.

Not all the articles are of equal merit, however, and some, it must be confessed, the reviewer found decidedly dull. Popular science is a difficult problem, and one cannot help wondering at times if, deliberately so written, it is not rather a mistake. To write popularly on any matter of erudition is difficult enough, but with science it is doubly difficult. The first essential of popular

writing must necessarily be "readableness," and yet with science there is often little choice between accuracy and dullness on the one hand, and on the other a form of writing which, if superficially readable, may be inaccurate and even grotesque in the impression it gives of science and scientific research.

The book is well printed. It contains some few misprints and grammatical clumsinesses which, even if they are excusable in journalism, should have been tidied up in a book. The publishers are to be commended on bringing out such a volume at the low price of five shillings.

T. M.

Practical Television. By E. T. LARNER. With a foreword by JOHN L. BAIRD. Pp. viii + 175. London: Ernest Benn, Ltd. Price 10*s*. 6*d*. net.

In the advertisement on the wrapper this book is described as a comprehensive survey of the whole field of television. Perusal of the book does not confirm this statement: on the contrary, in so far as it deals with recent developments, it is confined almost entirely to the work of Mr John L. Baird, who contributes a foreword to the volume. Only one of the 175 pages is devoted to the important achievements of the team of investigators, led by Dr H. E. Ives, working for the American Telephone and Telegraph Company, and even this page is rendered unintelligible by an incorrect reference to a figure. The result is that a quite erroneous impression is given of how and where progress is being made.

Many errors as to details could be indicated—for example, the absurdly inaccurate diagram on p. 162 purporting to represent the dispersion of light—but a book so one-sided in presentation is not entitled to be treated seriously. One cannot refrain, however, from noting with amused surprise Mr Baird's statement in the foreword that "Sport, Business, Art, Music, and all other avenues into which man directs his energies, are tainted with commercialism, self-interest, passion, and emotion." It appears to be implied that scientific research in general, and television in particular, are in these respects beyond reproach.

A. O. R.

THE SEVENTH INTERNATIONAL CONGRESS OF PHOTOGRAPHY

THE SEVENTH INTERNATIONAL CONGRESS OF PHOTOGRAPHY was held in London from the 9th to the 14th July, under the Presidency of Sir William J. Pope, K.B.E., F.R.S. The Meetings of the Congress were grouped under various Sections for the reading and discussion of the 70 odd papers which were before them. These Meetings were held in the Imperial College of Science and Technology, South Kensington, and were attended by the leading workers in photography in Europe and America. It is impossible, however, in the brief space of this article to do more than mention a few points from some of the more important papers presented at the Congress.

In Section 1 (*a*), Theoretical Aspects of Photography, Dr F. C. Toy gives, in his paper, an account of his method of attacking the problem of latent image formation from the physical side, and indicates that the mechanism of the primary stage is probably identical with that of the photo-conductivity effect, being due to the transfer of an electron from the halogen ion to the silver ion; whilst Dr F. Weigert considers that it is formed from free silver already in the emulsion, which acts as a catalyst. Prof. J. Eggert and W. Noddack review the various secondary reactions possible in the photo-decomposition of the silver halides, and discuss the rôle of gelatin as a bromine acceptor. Dr S. O. Rawling obtains the same change of sensitivity ratio on variation of the acidity of an emulsion, whatever emulsion formula is used, if it is made with the same kind of gelatin; whilst Dr A. Steigmann finds that the action of silver iodide in emulsions is also related to the sensitising properties of

gelatin. Dr Lüppo-Cramer discusses the phenomenon of the destruction of the latent image formed by light rays of short wave-length, by rays of other (usually longer) wave-length (the Hersechel effect), and regards it as due to a reversal of the primary light action. Dr F. M. Hamer gives a useful summary of all the known desensitisers, whilst Dr Baur advances a photochemical theory of sensitisation and desensitisation. E. P. Wightman and R. F. Quirk give a summary of previous work together with their latest results on the intensification of the latent image, and Otto Sandvik covers similar ground in a paper on the "Measurement of the Resolving Power of Photographic Materials."

Papers on sensitometric studies are contributed by L. A. Jones and by Prof. R. Luther, W. Seifert and W. Forstmann, the former giving a very complete study of contrast in photographic papers, whilst the latter show that plates and papers tested by (*a*) studio tests, and (*b*) the usual sensitometric tests, give results of about the same accuracy. L. A. Jones and M. E. Russel suggest that, in place of the H. and D. speed values usually given, it is preferable to state speed in terms of the minimum utilisable gradient, on the density log exposure curve of the plate, which will give a good tone rendering in the positive. L. A. Jones and V. C. Hall also contribute a paper giving a concise summary of their work during the past six years on the failure of the reciprocity law (Exposure = Intensity × Time). L. A. Jones and G. A. Chambers describe their High Intensity Time Scale Sensitometer, in which it is possible to give exposure times varying from 0·00025 sec. to 0·512 sec. at an intensity of 30 metre-candles on the plate; and S. E. Sheppard and H. Crouch describe a machine for the automatic development of sensitometric stripes for times ranging from half a minute to two hours or more.

Time was devoted at the Congress to discussion of a suitable standard of photographic intensity, and eventually agreement (subject to ratification by the various National Standardization Committees) was reached with regard to an international photographic unit of intensity for the sensitometry of negative material, which is to consist of a lamp run at a colour temperature of 2360° A. together with a selectively absorbing filter, similar to that worked out by Raymond Davis and K. S. Gibson of the United States Bureau of Standards and adopted by the Committee of the Optical Society of America as the photographic unit of intensity in their report to the Congress. This approximates to mean noon sunlight.

L. A. Jones puts forward a suggested systematic nomenclature for photographic sensitometry which is to be referred to the various National Standardization Committees for consideration. It was remarked by Dr C. E. K. Mees that a short name for the unit of photographic exposure in place of the present Candle-metre-second is an urgent necessity. In a paper by S. E. Sheppard and A. P. H. Trivelli a comparison of developers for sensitometric work is discussed, and it is suggested that a paraminophenol developer be adopted as standard. A critical survey of light sources, more particularly those for photo-chemical work, their energy distribution and its measurement, is given by H. N. Ridyard, and a comprehensive "Report on Turbidity" is presented by Dr F. C. Toy, E. R. Davies, B. H. Crawford and B. Farrow, special attention being paid to its application in the photographic industry. The term "turbidity" is often very loosely used, and they suggest its limitation to the meaning "visual covering power" which, moreover, is not a constant of the dispersion. A new constant, "undeviated light density per unit mass of disperse phase per sq. cm. of dispersion," is proposed, which is shown to agree with the theoretical deduction that its reciprocal is proportional to the grain size of the dispersion. A photo-electric instrument for measurement of this constant is outlined; and it is hoped that a full description of the instrument will be given later in this *Journal*.

In papers read before Sections 1 (*b*) and 1 (*c*), Photographic Practice and Scientific Applications of Photography, T. Smith discusses the difference between the wave and ray theories of image formation and shows why geometrical methods fail to solve some problems

in photographic optics, and lead to quite different laws from those given by the true wave theory. The scale of terms in use at the National Physical Laboratory describing the degree of definition of a lens is given, and is tentatively suggested for general use. H. W. Lee reviews the modern super-speed lens, suggesting that the limit of aperture has not yet been reached; while the problems involved in the testing of photographic shutters, and the methods used at the National Physical Laboratory, are discussed by Dr J. S. Anderson. N. Fleming describes the photography of sound waves by direct shadow methods, and L. J. Freeman deals with the various methods used in modern spectrography to photograph spectra. It appears that the longer X-ray spectra have now been photographed with optical gratings by Compton and Osgood, so that the former "no man's land" lying between 27 Å.U. and 136 Å.U. is now bridged, and spectra from the shortest X-rays up to the longest infra-red rays to which a plate can be sensitized, about 10,000 Å.U., have been photographed, with the exception of a small band between 27 Å.U. and 40 Å.U.

A paper by G. A. Clarke on cloud photography indicates the uses to which photography may be put in meteorology, and O. G. S. Crawford shows how aerial photography has been used advantageously in archaeological work. P. W. Cunliffe and F. D. Farrow contribute a paper on photographic methods of investigation of the colour of light sources and the reflecting power of coloured fabrics by comparison with a standard lamp, by means of a simple type of spectrophotometer. Prof. E. G. Coker outlines the way in which photography is being used by the engineer to determine stresses at the edges of transparent materials and how the data obtained from transparent models can be put to practical use in the design of structures.

In papers read before Section 1 (*d*), which deals with Industrial and Commercial Applications of Photography, including Kinematography and Colour Photography, Dr R. A. Houston describes a new colorimeter of a subtractive type, an instrument which gives comparative readings but can easily be calibrated so as to give absolute values. Commander H. E. Rendall gives a description of various types of one-exposure trichrome cameras, including valuable details concerning the methods used to obtain correct register. He considers that the new "aerial mosaic screen" camera system is full of possibilities. A paper by Schonne details the preparation of the emulsion for obtaining Lipmann interference photographs, whilst a new colour photographic mordant dye-printing process is described by Dr R. von Arx. Dr D. A. Spencer contributes five papers on ferro-prussiate, diazo and allied processes, in which he reviews the theory and indicates the advances which are being made in producing positive, photo-copying diazo papers for use in place of blue print papers, and also their adaptation for colour printing.

William Gamble presents a survey of the present position and further possibilities of photo-engraving. H. M. Cartwright deals with the progress of photogravure etching, and also describes a method of colour correction useful in photolithography and photogravure, whilst F. J. Tritton discusses the various uses of colour photography as aids to colour printing in the printing trade. In his paper, "Tone Rendering by Half-Tone Processes," A. J. Bull summarises our present knowledge of the subject, whilst E. A. Olland describes the chromium electro-plating of photo-engraved surfaces.

At the Congress the cinematograph group devoted most of its time to questions of standardisation, and various recommendations were put forward concerning details of standard and sub-standard film and similar matters. A. W. Kingston gave a paper on the adaptation of cinema projectors to take films containing a sound record as well as a light record. In the cinema theatre of the Imperial Institute, by kind permission of the Director, a paper and demonstration was given by C. F. Elwell on the "Talking Film."

In Section 3, papers by Prof. A. F. C. Pollard and Dr W. Clark deal with the International Decimal System of Classification, as applied to photography as a whole, and also to the indexing and storage of prints, negatives, microscope slides, etc. Ferdinando Lembo gives

a description of the method used in the photography of the papyri of Herculaneum, charred by lava from Vesuvius, so as to bring out the writings inscribed upon them.

During the Congress, three lectures were delivered; Mr F. C. Tilney spoke on "Pictorial Photography: the Relation of Technical Advance to further Artistic Achievement"; and Dr S. E. Sheppard delivered the 6th Hurter and Driffield memorial lecture, these two lectures being given in the House of the Royal Photographic Society. The third lecture was arranged in co-operation with the Institute of Physics and given by Dr C. E. K. Mees at the Institution of Electrical Engineers, on Physics in Photography. This constituted the 14th lecture of the Physics in Industry series of the Institute of Physics.

In connection with the Congress an Exhibition of Colour and Commercial Photography and Process Work, as well as of apparatus and prints of a scientific nature, was held. Under the latter head were noticed examples of natural history photography and micrography, and photo-micrographs of geological and metallurgical interest. Prof. Garwood exhibited some slides of rock sections in colour, taken by the autochrome process. Among exhibits of survey and record work may be mentioned a collection of prints illustrating the photographic records and survey of Sussex, and a five foot square aerial mosaic of the Isle of Wight, by the Royal Aircraft Establishment. The Research Department, Woolwich, contributed some transparencies illustrating the radiographic examination of castings for faults and the spectrographic examination of materials by X-rays. Messrs Ferranti Ltd. exhibited a photograph of a million volt spark 9 ft. 8 in. long, a close examination of which revealed that what at first appeared to be a series of white dots were in reality the faces of a number of onlookers. Prof. G. I. Finch showed his versatility in his exhibits of radiographs of a thermionic valve; photographs of a steady discharge current in electrolytic gas, and an excellent series of photographs taken on the 1922 Mount Everest expedition.

An interesting exhibit was Dr Fraser's high speed drum camera, which he uses for obtaining large photographs of small fast-moving flames and explosions of solid matter. With this apparatus, a full description of which has been promised for a later number of this *Journal*, it is possible to move the film past the camera slit at speeds up to 200 metres per sec. (about 7½ miles a minute). Another exhibit from the same laboratory (Department of Chemical Technology, Imperial College of Science and Technology) consisted of two optical recording manometers and a drum camera used by Prof. W. A. Bone and Drs Newitt and Townend in their recent researches on gaseous explosions at high pressures.

Prof. A. F. C. Pollard exhibited a series of photomicrographs showing the track of the glazier's diamond over plate glass before and after rifting. These indicated that rifting does not take place until the track width, which varies with the pressure on the diamond, reaches a critical value. A collection of radiographs, mostly of medical and surgical interest, were shown by Dr C. Thurston Holland, Messrs Ilford Ltd. and Messrs Kodak Ltd., together with some early radiographs of shells and also a particularly clear radiograph of a pair of prism binoculars by Dr G. H. Rodman.

In the Galleries at the East End of the Science Museum, the Will Day collection of early cinematograph apparatus, a collection of Hurter and Driffield's and of Fox Talbot's apparatus, on loan from the Royal Photographic Society, and of early Kodak cameras on loan from Messrs Kodak Ltd., were arranged. It was noticed that Hurter and Driffield's first Sector Wheel was made of cardboard in 1891, whilst the earliest Kodak shown, capable of taking circular photographs 2½ cm. in diameter and up to 150 exposures at one loading, came into existence three years earlier.

In the Trade Exhibition, held in the large Chemistry laboratory of the Imperial College, it was pleasing to notice the advent of an all-British film stock, which is non-inflammable; unbreakable, non-inflammable lantern slides were also shown. At the House of the Royal Photographic Society a collection of British pictorial photographs and photographs of pictorial and historical interest were on view throughout the Congress.

At the close of the Congress, an invitation from the German delegates for the Congress of 1931 to be held in Dresden was accepted. Much appreciation was expressed at the very successful organisation of the present Congress, and thanks were tendered to the Royal Photographic Society and especially to Dr Walter Clark, Hon. Secretary of the Organising Committee.

J. O. C. VICK.

THE PHYSICAL SOCIETY AT BRISTOL

A VERY successful and well attended provincial meeting of the Physical Society was held at Bristol on July 7th, at the invitation of Professor A. M. Tyndall, in the new Henry Herbert Wills Physics Laboratory of the University. The formal proceedings included

The Henry Herbert Wills Physics Laboratory

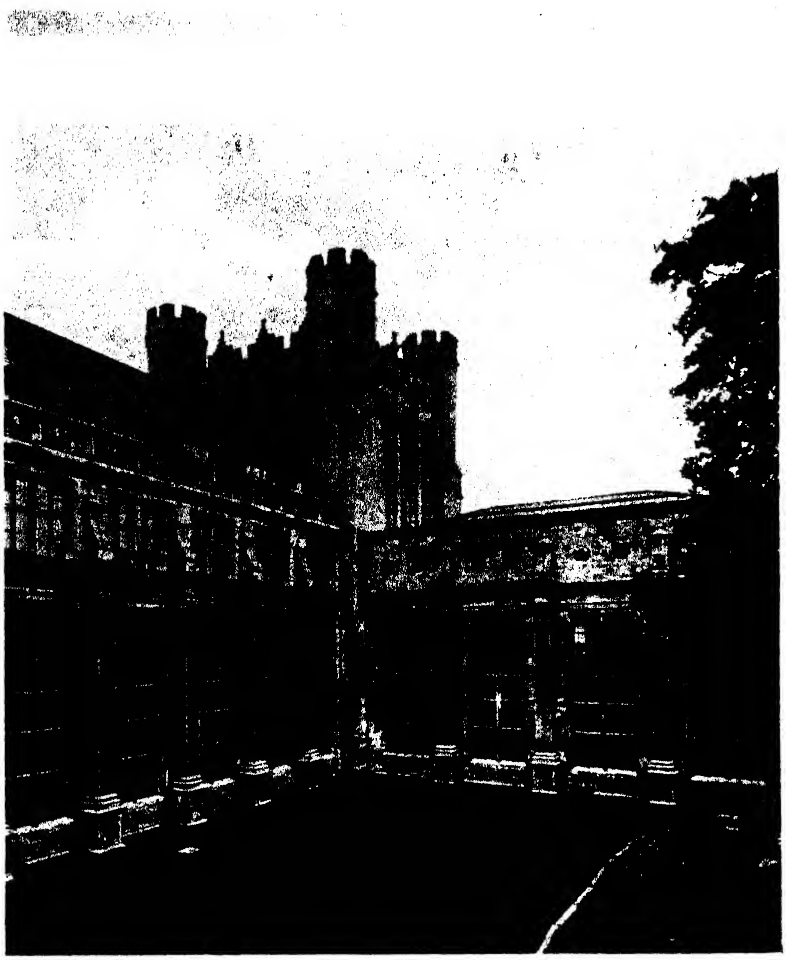
papers by Professor Tyndall and members of his staff and students, and after the meeting members of the Society had an opportunity, which was greatly appreciated, of inspecting the new laboratory and the work in progress there.

Although the Henry Herbert Wills Physics Laboratory was formally opened by the President of the Royal Society on 21st October, 1927, it is doubtful if physicists generally in this country realize the magnitude and importance of the achievement which this building represents. It may truly be said of it that the best possible use has been made of a great opportunity. The President of the Physical Society, Dr W. H. Eccles, at the meeting, expressed the opinion that the new buildings constituted one of the most striking contributions of industry to learning in the history of this country. It would be difficult to imagine a happier outcome of the concert of effort of industry, science, and art.

It is a new thing in the history of physics in the universities, and perhaps an augury for the future, to find this mother of the sciences installed, the sole occupant in a spacious

building which is architecturally of great dignity and beauty, placed on an eminence overlooking its surroundings, in this case the University and the whole city of Bristol, a landmark for many miles around. The interior planning and equipment are no less remarkable than the exterior, and give ample evidence of the care and thought which have been devoted to them.

The plans of the Laboratory were drawn up by the Architects, Messrs Oatley and Lawrence, in co-operation with the Professor of Physics, Professor Tyndall, and in close



View from the west, showing portions of both wings

consultation with the donor, the late Mr Henry Herbert Wills. The result of their efforts is a building which satisfies every aesthetic sense as well as scientific and practical consideration, and stands as an example of the harmony which may be achieved from elements seemingly diverse.

Other physicists will join the members of the Physical Society in congratulating Professor Tyndall on his share in the making of the new Laboratory. They will wish him every success in gathering into it the school of students and research workers for whom its spacious rooms are intended, and will look to Bristol in the future to see the growth of that centre of physical teaching and research which the benefactions of the late Mr H. H. Wills have made possible.

STANDARDIZATION OF OPTICAL PROJECTION APPARATUS

At the suggestion of the Optical Society the British Engineering Standards Association has set up a committee for the standardization of Optical Projection Apparatus. In accordance with the usual practice of the Association a preliminary Conference of representatives of interested bodies was held on June 14th, at which the proposal was considered.

In the original suggestion made by the Optical Society in the matter the difficulties experienced owing to lack of standardization in projection apparatus, particularly that used for teaching, were pointed out. The Society proposed as a commencement of the work that the following components should be dealt with:

(*a*) Dimensions and focal lengths of objectives.
(*b*) Diameter of sliding barrel.
(*c*) Dimensions of lantern condenser and lenses for same.
(*d*) Size of lantern tray.
(*e*) Height of optical centre.
(*f*) Dimensions of lantern slide carrier.

In the discussion which followed criticisms of these proposals were made on points of detail, but the opinion of the Conference was entirely favourable to standardization, and it was unanimously resolved to recommend that a Committee be appointed for the work.

Accordingly, the necessary steps are being taken by the British Engineering Standards Association, and a representative Committee has been appointed to draw up a specification.

CATALOGUE

A General Catalogue of the Manufactures of Adam Hilger, Ltd., March, 1928. Adam Hilger, Ltd., 24 Rochester Place, Camden Road, London, N.W.1.

The ever-increasing demand for new types of optical instruments of high precision is reflected in this latest catalogue issued by Messrs Hilger, which contains descriptions of many more instruments than previous catalogues have done. As many of the instruments have been described from time to time in this *Journal*, it will suffice to give here merely a brief résumé of the contents of the various sections of the catalogue. Section D deals with wave-length spectrometers, monochromators, and specialized spectroscopes. The 1926 model wave-length spectrometer and a simple ultra-violet spectroscope are new instruments. Section E contains descriptions of spectrographs. Special attention is directed to the large instrument with interchangeable optical systems, the "All Metal" quartz spectrograph, the vacuum grating spectrograph, the large aperture glass and quartz spectrographs, and the McLennan fluorite vacuum spectrograph. Müller's X-ray spectrograph is included in this section. Section F deals with accessories for the instruments in Sections D and E and includes lenses, slits, pumps, vacuum tubes, lamps, electrodes, spectrum comparators, thermopiles, galvanometers, photo-electric cells, selenium detectors, and sparking apparatus. Section H contains spectrophotometers, colorimeters, and apparatus for sensitometry, including the Moll recording microphotometer, made by Messrs Kipp and Zonen, for the sale of which Messrs Hilger have been appointed sole agents for the British Empire. Section K deals with diffraction gratings. Section L with micrometers and spherometers, and Section M with polarimeters and refractometers. Section N includes Michelson, Fabry and Pérot, and Hilger interferometers.

When a catalogue reaches the dimensions of this one it is rather confusing to find that the pages are not numbered consecutively throughout, but only in each of the sections. The system of numbering the items could also with advantage be improved by the introduction of the decimal system, so that all modifications of a particular instrument would be given the same whole number following the letter, but different decimal integers. Such a system would allow of the items being arranged in their natural sequence and at the same time in a mathematical sequence as regards their identification numbers. Apart from these minor faults, the catalogue has been well produced.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V SEPTEMBER, 1928 No. 9

A SIMPLE ULTRA-VIOLET FLUOROPHOTOMETER.

By B. T. SQUIRES AND J. H. JEFFREE. From the Department of Biochemistry, Oxford.

[*MS. received, 12th June*, 1928.]

ABSTRACT. A simple apparatus is described by which the fluorescence under ultra-violet light of various solutions may be compared with considerable accuracy.

INTRODUCTION

DURING the course of work upon the fluorescence of substances of animal origin when exposed to ultra-violet light, it became necessary to devise some method whereby the fluorescence of such substances, especially of urine produced under various conditions, might be quantitatively compared with some standard. To meet this need the apparatus was constructed which is described below.

GENERAL

The liquids to be compared are contained in two similar flat-sided thin glass cells, which are exposed to ultra-violet light from a mercury vapour lamp fitted with a filter of nickel glass, which transmits mainly the group of lines round 3655 Å, and cuts out the visible radiation almost completely. Pencils of fluorescent light from the two cells are received into an optical device by which their relative intensities can be visually compared. Between the cells and the comparator is mounted a square (or circular) optical wedge through which both pencils pass, and by rotation of this wedge in its own plane the relative intensities of the two pencils may be altered. The angle of rotation of the optical wedge necessary to equalize the apparent intensities of the two pencils gives a measure of their relative actual brightness.

DETAILS OF THE APPARATUS

1. *The Cells.* (*C*, Fig. 1.) These are approximately 2 in. high, 1 in. wide and $\frac{1}{4}$ in. deep. They are made of thin glass, with flat (polished) faces to receive and emit light. They are supported on a shelf *B* which is fastened to a partition F_1 running across the box in which the apparatus is mounted, so as to be replaceable in fixed positions after removal for cleaning and filling.

In the partition behind each cell is a circular hole $\frac{1}{2}$ in. diameter, through which the emitted fluorescent light passes to the comparator. The centres of the holes are 1 in. apart. The cells receive ultra-violet light through their front faces, the light being directed downwards at an angle of about 45°. The radiation which passes through the cells and the holes in the partition F_1 thus falls on the blackened floor of the box instead of entering the optical wedge and comparator. This precaution is necessary because many optical wedges

are strongly fluorescent. To ensure even illumination of that part of the liquid in each cell which can be viewed through the comparator it is necessary to prevent entry of light into the top surface of the liquid, which is done by the removable screen D.

2. *The Optical Wedge.* This is square or circular in shape, about $1\frac{1}{2}$ in. diameter, with a density gradient of about 0·25 per cm. or a little more. It is an ordinary neutral optical wedge such as can be obtained from optical manufacturers. It is mounted about $\frac{1}{2}$ in. behind the partition F_1, so as to rotate in that position in its own plane. In the experimental model it was fastened with adhesive wax to a short piece of brass tube about $1\frac{1}{2}$ in. diameter, which was carried in a hole in the wooden partition F_2, in which it rotated without slackness. Also attached to the brass tube was a graduated metal circle about 4 in. diameter, marked in degrees plus and minus from zero, which projected a short way through a slit in the

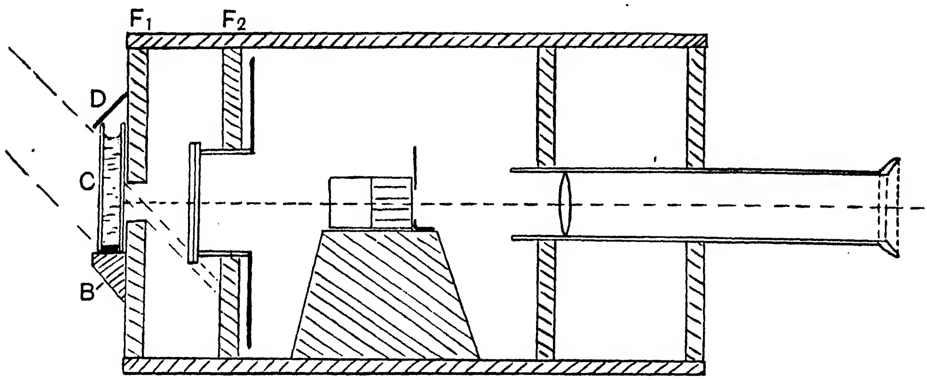


Fig. 1

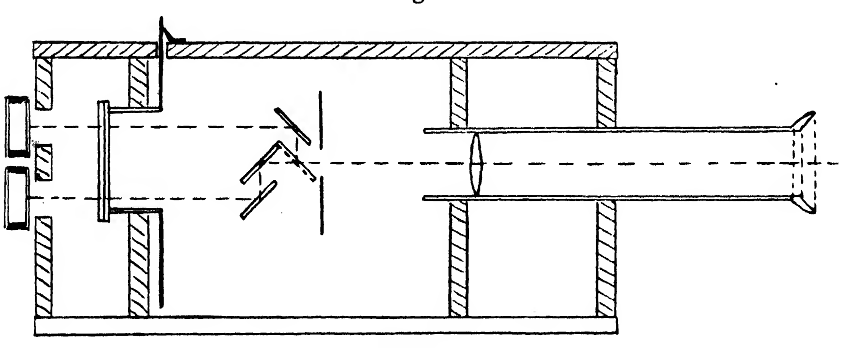


Fig. 2

right-hand side of the box. To render this possible the centre-line of the whole apparatus is not central in the box, but displaced to the right hand side. By means of the projecting disc the wedge can be rotated and the angle of rotation measured. The necessary calculations to determine therefrom the variation in observed intensity of the cells are given later.

3. *The Comparator.* This is similar in principle to the usual type, found in colorimeters, etc., but slight variations are necessary owing to the faintness of the light to be measured. On this account a comparator was arranged (with thin glass mirrors instead of the usual prisms) in which the field was divided into horizontal bands, from each cell alternately. Part of the silvering was removed from one of the mirrors in this form, as shown in Fig. 2.

To obtain the maximum light grasp no stop was placed near the eye in the eye-piece. The mirrors of the comparator were adjusted so that the images of the holes behind each cell in the partition F_1 should coincide, and the focal length of the viewing lens arranged so that these images were nearly $\frac{1}{2}$ in. across. Hence the "exit pupil" of the instrument

was limited only by the pupil of the eye, giving maximum light grasp. The errors thus introduced are negligibly small.

4. *The Enclosing Box*. This is of wood, blackened inside, with a detachable lid for convenience. It is mounted in a fixed position with respect to the mercury vapour lamp and filter, to insure constant conditions of illumination.

5. *The Mercury Lamp*. This may be of "vacuum" type, run at fairly high intensity, and enclosed in a box with a window of "nickel" glass.

The whole apparatus is used in a dark room.

THEORETICAL

The theory of the action of the wedge is as follows:

The wedge is of the usual type in which the "density" at any point is proportional to the distance from that point to an imaginary reference line of zero density, at which the wedge would be perfectly transparent. The density is defined as the logarithm to base 10 of the ratio between the intensities of a beam of light before and after passage through the wedge.

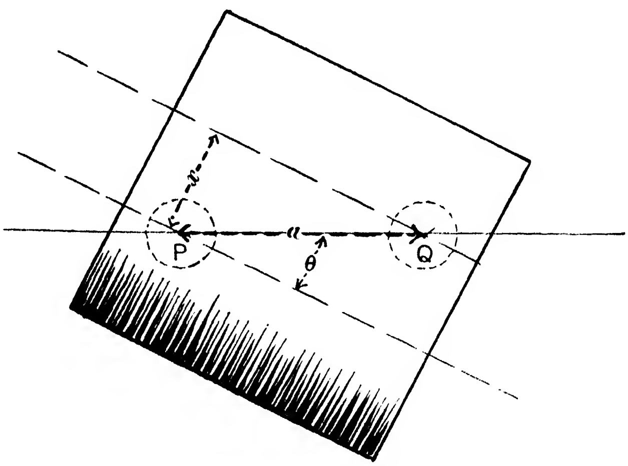


Fig. 3

Let I_0 = intensity of incident light.
Let I_1 = intensity of transmitted light.

Then
$$\text{density} = D = \log_{10} \frac{I_0}{I_1}.$$

The arrangement of the wedge in the apparatus is shown in Fig. 3, in which the circles at P and Q represent the two pencils of light from the cells, whose centres P and Q are separated by the distance a. Let the densities of the wedge at these points P, Q be D_1 and D_2 respectively. Then the beams at P and Q are cut down in the ratios R_1 and R_2 respectively where

$$\log_{10} R_1 = D_1,$$
$$\log_{10} R_2 = D_2.$$

The ratio, therefore, in which Q is cut down relatively to P is

$$\frac{R_2}{R_1},$$

and

$$\log_{10} \frac{R_2}{R_1} = \log_{10} R_2 - \log_{10} R_1$$
$$= D_2 - D_1.$$

We need therefore consider only the difference of density between these two points. Now the density at each point is proportional to its perpendicular distance from the zero line, so that the difference of density between P and Q is proportional to the difference between their perpendicular distances from this line.

In Fig. 3 this difference of perpendicular distance is x. If the angle between the zero line and the line of centres, PQ, be θ, as in the figure, it is obvious that

$$x = \overline{PQ} \sin \theta,$$
$$= a \sin \theta.$$

When $\theta = 90°$, then x reaches its maximum value, equal to a, and the difference of density is at a maximum also. Let us call this maximum difference of density K. Then the difference of density for any angle is proportional to x, and is, therefore, $K \sin \theta$. Therefore the ratio in which beam Q is cut down relatively to beam P is the antilogarithm of $K \sin \theta$.

Although this result has been obtained only for narrow pencils passing through the centres of the beams, P and Q, it is easily seen to hold for the complete beams if they are similar in shape. For each beam may be resolved into an infinite number of elementary rays, to each of which corresponds a ray in the other beam at a distance a along a line parallel to the original line a. For each of these pairs of rays the same ratio will be found. Hence this ratio is accurate when applied to the pencils as a whole.

In using the instrument, the wedge is turned till the field of the comparator appears uniformly illuminated; *i.e.* till the transmitted beams P and Q are of the same intensity. Then since Q has been cut down relatively to P in the ratio

$$\text{antilog. } K \sin \theta.$$

Q must originally have been brighter than P in this ratio (or fainter, if $K \sin \theta$ is a minus quantity).

Adjustment of the Apparatus

Adjustment of zero reading. It is necessary that at zero reading of the graduated circle the zero-line of the wedge should be parallel to the line PQ which is determined by the mirrors of the comparator. This is ensured as follows:

The wedge is removed, and the apparatus directed towards a white surface. By varying the illumination the comparator field is made to appear uniform. The wedge is then replaced, other conditions remaining the same, and adjusted till the field is again uniform. The pointer is then set to read zero at this position. Two or three settings should be made in this way and the average position taken.

Calibration of the Instrument

With suitable apparatus the constant K can be determined directly, since it is the product of the "wedge" constant and the optical separation of the beams P and Q. This was done in the experimental apparatus.

The constant K may, however, be determined by measurements with the instrument itself since it is found that the intensity of fluorescence of many solutions is proportional over a wide range to the concentration of fluorescent substance. Errors occur in very dilute solutions owing to the fluorescence of the solvent and the glass cells, and in strong solutions owing to appreciable absorption either of the ultra-violet or of the emitted light.

To calibrate in this way, solutions of a suitable substance are prepared, each having half the concentration of the previous one. For instance, urine may be diluted with distilled water in the proportions 1/2, 1/4, 1/8, 1/16, 1/32, 1/64. The dilution 1/16 is placed in the "standard" cell and the other solutions in turn in the other, and readings taken of the wedge

rotations necessary to equalize the bands in the comparator field. The sines of these angles are plotted against the logarithms of the concentrations, and over a considerable range they should lie on a straight line. Over this range a value of K can be found to fit the measurements.

The very dilute solutions, if their fluorescence be calculated with this value of K, will appear too bright. With accurate measurements this excess will appear roughly constant, and is to be set down to fluorescence of solvent and cells. It is sometimes possible to measure it directly by filling one cell with solvent only. Tap water is often markedly fluorescent, and it appears that ordinary distilled water is more so than "conductivity" water. The purest solvents should therefore be used.

It may be found that when equal dilutions are placed in the two cells the angular reading is not zero. This is due to uneven illumination, or unequal reflecting power of comparator mirrors, etc. It is most easily allowed for by subtracting (algebraically) the sine of the angle read for equal solutions from the sine of all readings before multiplying by K. In the experimental apparatus values of K were determined by both the methods given above, with results in close agreement.

It is, of course, possible to dispense with calculation altogether, and calibrate the instrument empirically with known concentrations of a given fluorescent substance measured against a standard. If this is done the relative positions of lamp and measuring apparatus should be fixed, and the calibration should be checked occasionally to guard against error due to possible change of illumination, reflecting power of comparator mirrors, etc.

The low values of fluorescence found with concentrated solutions are presumably due to absorption either of ultra-violet or of fluorescent light in appreciable proportion by the solution. It is necessary to work with such small concentrations that errors from this source are avoided.

Standard Solution

A standard solution should be used which emits a fluorescent light similar in colour to that of the substance being measured. Care should be taken that the fluorescence remains constant. With quinine this was noticeably not the case. The following standard solution is apparently constant if kept in the dark and is suitable for measuring the fluorescence of urine.

100 c.c.	1 per cent. sodium salicylate,
30 c.c.	0·1 molecular sodium carbonate,
15 c.c.	0·1 per cent. eosin solution,
100 c.c.	conductivity water.

Fresh standard solution is placed in the cell for each series of measurements, to avoid errors due to evaporation, effect of ultra-violet light, etc.

Conclusion

The above apparatus has been thoroughly tested in the measurement of eosin, urine and quinine, and in the case of the first two substances it has been possible consistently to obtain results accurate within 2 per cent., which is as close as could be expected in view of the difficulties of measurement.

We desire to acknowledge our indebtedness to Professor R. A. Peters and Dr G. M. B. Dobson for much valuable criticism and advice; also to Professor M. S. Pembrey, for facilities extended to one of us (B. T. S.) at Guy's Hospital.

A SIMPLE HIGH-SPEED ROTARY PUMP. By L. E. BAYLISS AND E. A. MÜLLER*.

From the Department of Physiology and Biochemistry, University College, London.

[*MS. received*, 11*th February*, 1928.]

ABSTRACT. A small rotary pump is described, suitable for liquids or gases, in which the fluid is forced through a rubber tube by the pressure of a series of rollers passing along it.

THE pump about to be described in this paper makes use of a rubber tube compressed by a series of rollers which pass along it from one end to the other, driving the contents before them, and although pumps of this nature have been constructed at intervals for some years, their advantages do not seem to be generally recognized, and they are not easily obtainable. The chief advantages are that a very satisfactory pump can be made by any fairly competent mechanic in a few hours, it can be designed so as to deliver any amounts (within limits) of air or any liquid, the output being independent of the pressure up to at least 1/2 atmosphere, and the fluid pumped comes into contact with glass and rubber only.

The essentials are shown in Fig. 1, and consist, virtually, of an ordinary roller bearing in which, at one point, the outer race has been cut away and replaced by a rubber tube, backed by a plate shaped so as to be concentric with the bearing. The distance of this backing plate from the rollers is so adjusted that the lumen of the tube is just obliterated by them, and its length is such that never less than two rollers are in contact with the tube at one time. In this way, each roller, as it passes along the tube, expels the whole of the contents between it and the next in front, and there is never any free passage from one end of the tube to the other; the pumping action is thus completely positive.

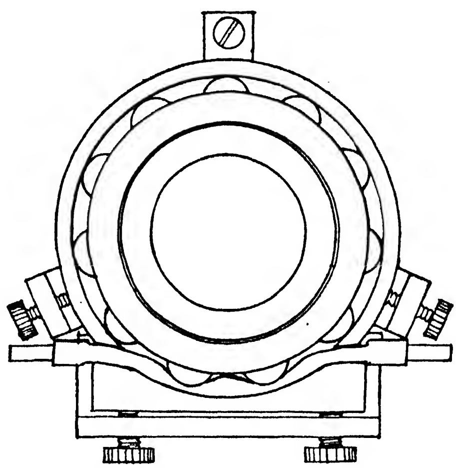


Fig. 1

The bearing is mounted on a shaft, provided with a driving pulley and a simple thrust bearing, or, of course, it can be attached directly to the spindle of a motor. The outer race should be supported in such a way that the open ends, where the rubber tube is inserted, can be tightened on to the rollers, otherwise they may tend to slip on one of the races and rotate on their own axes without revolving around the axis of the bearing as a whole; for this reason, also, it is inadvisable to reduce the number of rollers to below ten. The maximum diameter of rubber tube that can be used is set by the difference in radius between the outer race and the cage holding the rollers in place, so that this should be made as large as possible. The width of the rubber tube when compressed obviously must not exceed the width of the rollers.

It appears to be necessary to use red rubber tube, not black, for pumping gases, since the black is inclined to be sticky and to fail to open out sufficiently rapidly after the passage

* Of the Kaiser Wilhelm Institut für Arbeitsphysiologie, Berlin.

of the rollers. The presence of water, however, prevents this sticking to some extent. Glycerin should be used as a lubricant, and the whole pump can with advantage be mounted in a glycerin bath.

The dimensions of the most satisfactory pump at present in use are as follows:

Diameter of outer race	62 mm.
Diameter of rollers	10 mm.
Number of rollers	11.
Inside diameter of rubber tube ...	2 mm.
Outside diameter of rubber tube ...	4 mm.
Maximum output	500 c.c. per minute.

These figures were largely determined by the fact that the pump was constructed out of an ordinary roller bearing, but it is more satisfactory, whenever convenient, to make use of fresh material throughout.

In Fig. 2 is shown the output per minute of this pump plotted against its speed in revolutions per minute, and it will be seen that the relation between them is rectilinear up to a

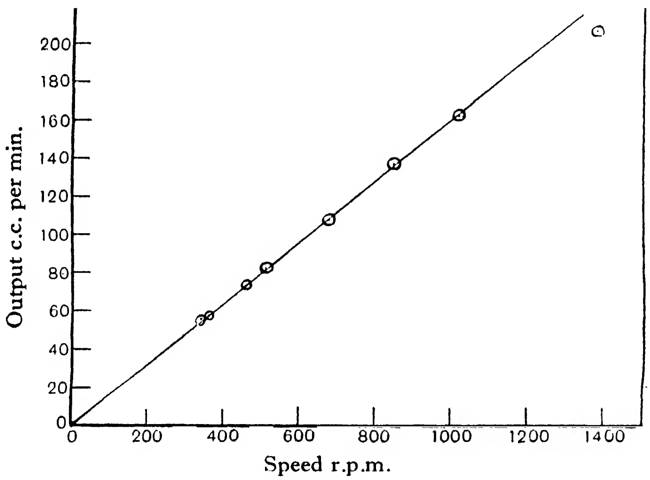


Fig. 2

speed of 1100 r.p.m. The subsequent falling off is probably due to the fact that the rubber tube does not have time to open out completely after the passage of each roller. The uniformity of the output per revolution within these limits makes it possible to calculate the total amount of fluid passed by the pump in a given time from the total number of revolutions, with an uncertainty of only 1 per cent. or 2 per cent.; each piece of rubber tube has, of course, to be calibrated separately. A similar pump with a rubber tube of 7 mm. internal diameter has given an output of 12 litres per minute.

The rubber tube has to be renewed fairly frequently; in the case of the pump whose dimensions are given, after about every 24 to 36 hours continuous running at full speed, depending on the age and quality of the rubber; the larger sizes require more frequent renewal owing to the greater amount of flexion at the sides of the tube. The renewals are very easily and quickly effected, but it would seem probable that large outputs are best obtained by using two or more small tubes alongside one another beneath the same set of rollers.

Pumps of this pattern may be obtained from Messrs C. F. Palmer (London) Ltd., Effra Road, Brixton, London, S.W. 2.

A LONG-PERIOD GALVANOMETER.

By D. C. GALL.

[*MS. received*, 14*th May*, 1928.]

ABSTRACT. The magnetic properties of a galvanometer coil are used to increase its periodic time instead of decrease it as is usually the case.

DURING experimental work in connexion with galvanometer design a curious phenomenon was discovered which was new to the writer. One of the chief obstacles in sensitive moving coil galvanometer performance is the residual magnetism of the coil. This is reduced in various ways, but is always present. It is felt very badly when a long-period galvanometer is required, the control from the residual magnetism of the coil being greater than that of the suspension strip, in many instances.

A coil of the form given in Fig. 1 was suspended upon a bronze strip between the magnet poles shown, with a $\frac{3}{8}''$ dia. core piece. The magnet strength was 360 lines per square cm.; the form of the field approximately radial in the gap. Under these conditions the periodic time was 8·2 seconds. The core piece was then removed. The result of this was to increase the periodic time of the coil to 21 seconds.

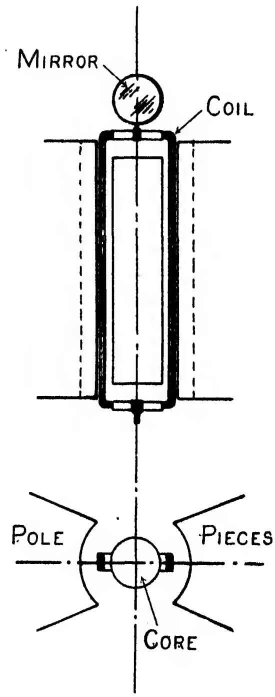


Fig. 1

By adjusting the field distribution the periodic time can be increased indefinitely, but the adjustment becomes very critical after about 25 seconds. Finally, the coil becomes unstable and takes up a new position. To produce this effect the coil must be magnetised first in one type of field, and then the distribution of the flux changed.

The cause must be in the axis of polarisation produced by the initial magnetisation exerting a couple in opposition to the strip control when the flux is concentrated at the edges of the poles, but the writer has been unable to verify the exact state of affairs in the coil. An attempt to reproduce the phenomenon with minute magnets has failed. The coil remains quite stable and cannot be remagnetised by direct current fields of considerable strength in any other axis.

A galvanometer arranged upon this plan can be made extremely sensitive, since the sensitivity rises almost as the square of periodic time. The zero keeping qualities, however, are not good, and the scale law is very uneven. Such an instrument would be very unsuitable for ballistic work.

The following table gives the performance under the different conditions.

Table I

Natural period of suspended coil out of field 9·5 seconds. Coil then introduced into radial field produced by core piece as shown in Fig. 1. Magnet strength 360 lines per square cm.

Periodic time	Deflection, mm. per micro-amp.	Critical damping	Diameter of core
8·2 secs.	350	650 ohms	$\frac{3}{8}''$
After removal of core piece			
21 secs.	1300	500 ohms	None

That the effect depends upon the distribution of the flux is demonstrated by the results obtained by using core pieces of different diameters with all else unchanged.

Table II

Diameter of core piece	Periodic time secs.
None	21
$\frac{1}{8}''$	25
$\frac{3}{16}''$	18
$\frac{1}{4}''$	11
$\frac{5}{16}''$	10
$\frac{3}{8}''$	8·2

These results suggest that the orientation of the flux where it crosses the coil governs the behaviour.

A UNIVERSAL X-RAY PHOTOGONIOMETER.

By J. D. BERNAL, B.A.

(*Continued from p.* 250)

Beam Limited by Crystal only

In the first case the aperture A_2 only serves to cut down that part of the beam which does not strike the crystal. To do this most effectively it is obvious that it should be as near the crystal as possible and that only a fine border of rays should be allowed to pass between it and the crystal. The simplest way to ensure this is to look at the crystal through the two apertures either by the naked eye or with a low-power microscope and arrange the second aperture so that it appears almost filled by the crystal.

A rigorous treatment of the theoretical size and shape of spots for different sizes and shapes of apertures and crystals and for different reflecting positions will not be attempted here. It is doubtful if it would be of any practical value in view of the physical phenomena of absorption, scattering and crystal imperfections. We may, however, obtain an approximate solution leading to results of some utility.

Consider first the simplest case of all: a spherical crystal of radius c illuminated by a beam from an aperture of radius a at a distance b (see Fig. 3). If the incident beam contained only parallel rays the reflected beam would be a cylinder circumscribing the crystal. Actually the beam is divergent and each point of the circle of contact of the cylinder and crystal gives rise to a cone of rays whose divergence can be calculated from that of the incident beam. Now the divergence of the incident beam, as can be seen from Fig. 3, cannot be greater than $\frac{a+c}{b}$. The theoretical reflected beam must therefore lie wholly within the surface which is the envelope of the cones of reflection for rays of this divergence whose axes are all generating lines of the cylinder of parallel ray reflection. The reflected beam approaches this limiting surface most closely for reflections of small glancing angle and in no case does it fall much short of it, so that, as all the physical factors contribute to increase the divergence of the beam, we may without much error take the limiting surface as representing the surface of the beam. We may accordingly consider the spot on the plate to consist of two parts, the one an ellipse of constant size formed by the trace of the cylinder of reflection, the other a border around this ellipse whose depth is proportional to the divergence of the incident beam and to the distance from the crystal to the plate.

On the rotation diagram the spot will be approximately circular and its radius in $\xi\zeta$ units will be

$$\frac{a+c}{b}$$

where r is the distance between the crystal and the spot. Now the radius of the spot is inversely proportional to the geometrical resolving power of the instrument, which is one of our objects to keep as large as possible. From the form of the above expression we can

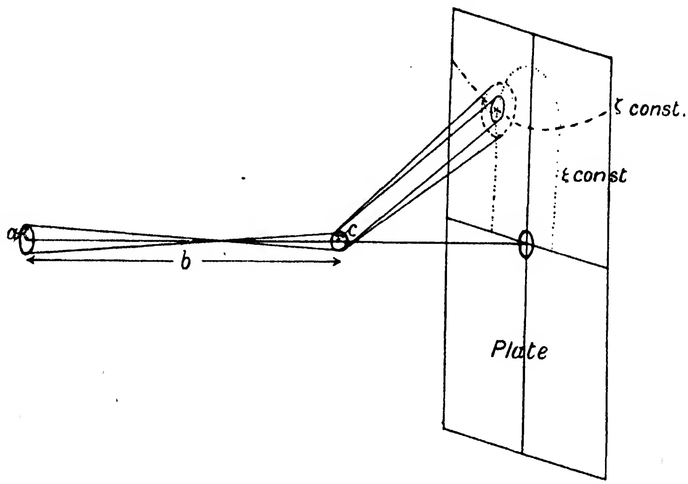


Fig. 3

deduce two important results; remembering that a and c, b and r are supposed of the same order of magnitude:

(a) *For the same size of crystal and aperture we can increase the resolving power more rapidly by increasing the distance of the aperture than that of the plate.*

(b) *For the same distances of plate and aperture we can increase the resolving power more rapidly by decreasing the size of the crystal than by decreasing that of the aperture.*

Intensity Considerations

To arrive at any quantitative estimate of the best dimensions to adopt for the apparatus and crystal we must further bring in considerations of intensity. It is obvious that by cutting down the sizes of the aperture and crystal and by lengthening the distances between them we can increase the geometrical resolving power to any extent we like. The limit to this increase is fixed by physical factors such as imperfections of the crystal, scattering and finite size of diffracting peak. Before this limit is reached, however, it is often uneconomical to increase the geometrical resolving power beyond a certain point, as it involves such an increase in the time of exposure. The problem is therefore to find the dimensions of aperture and crystal which will give the maximum of resolving power for a required intensity of spot (or more accurately photographic density, which for X-rays is proportional to X-ray intensity × time).

The mean intensity of any spot I is simply

$$I_s = \frac{\text{Total radiation falling on spot}}{\text{Area of spot}}$$

$$= \frac{\text{Time of exposure} \times \text{Intensity at crystal} \times \text{Reflecting efficiency}}{\text{Area of spot}}.$$

The intensity of radiation at the crystal is simply $I_a \pi \frac{a^2}{b^2}$ where I_a is the intensity outside the first aperture. The area of the spot is $\pi \frac{r^2}{x^2} = \pi \left(\frac{r}{b}(a + c) + c\right)^2$ where x is the resolving power. The reflecting efficiency of the crystal for any given plane is unfortunately impossible to calculate. It must be, however, some function of F, the structure factor of the plane*, of c the radius of the crystal and of μ its effective absorption, which in its turn depends on the size and nature of the crystal and of the reflecting plane. In two special cases this function is known. If the crystal is indefinitely small or its absorption negligible then the efficiency varies as the volume, *i.e.* as c^3. If the crystal is large or its absorption high, then it varies as the area, that is as c^2. Now all other cases lie between these extremes, so that we may write for the efficiency of reflection $kc^{p(c\mu)}$ where k is a constant and $p\ (c\mu)$ a function of c and μ whose value lies between 2 and 3.

For highly absorbent crystals the method of calculation employed is no longer strictly justifiable. Here the reflected beam comes only from the outer layers of the crystal on the side on which the reflection takes place, and produces a crescent-shaped spot of much smaller area than that from a non-absorbent crystal of the same size. This leads actually to a greater resolving power than that calculated. The advantage gained is, however, discounted by the fact that these crescent-shaped spots do not correspond to the centre of the crystal and lead therefore to erroneous estimates of ξ and ζ.

We now have for the intensity of the spot

$$I_s = k'I_a \frac{a^2 c^{p(c\mu)} x^2}{b^2 r^2} = k'I_a \frac{a^2 c^{p(c\mu)}}{\{ra + (b + r)\, c\}^2}$$

where k' is a constant. We are still unable to find the conditions for maximum resolving power except when $p\ (c\mu)$ is known.

If $p\ (c\mu) = 2$ the case for a large crystal or high absorption x is a maximum where

$$\frac{a}{c} = \frac{b + r}{r}.$$

If $p\ (c\mu) = 3$ the case for a small crystal or low absorption x is a maximum where

$$\frac{a}{c} = \frac{2\,(b + r)}{3r}.$$

So that in general the conditions for a maximum are between these values. From this we see that if $b = r$ it will always be necessary, to obtain the best results, to have the radius of the crystal slightly less than the radius of the aperture A, and that the more absorbent the crystal the smaller should it be compared to the aperture.

In determining the absolute size of the crystal there are two other factors which must be taken into account: extinction and crystal imperfections (mosaic structure). These are roughly complementary. A perfect crystal always shows marked extinction affecting chiefly the planes of low indices, while an imperfect crystal will give a larger cone of reflected rays, both phenomena decreasing the product Intensity × Resolving Power. For the same sample of crystal the larger the crystal the larger are both these effects, and this is an important reason for keeping the crystal small. More serious still are the differential effects of extinction on the intensities of the different crystal planes. This is a great hindrance to accurate intensity measurements. Darwin† has shown that while extinction cannot be entirely eliminated by using very minute crystals yet its amount can be sensibly diminished. This gives us an additional and weighty reason for preferring small crystals to large.

* *X-rays and Crystal Structure*, p. 212.

† *Phil. Mag.* **43** (1922).

The results of this theoretical discussion are amply confirmed in practice. Accurate results are difficult to obtain from a crystal of 1 mm. diameter or over. The spots are large and diffuse no matter how fine the aperture is. Crystals of 0·2 mm. diameter are about the ideal size. Below this size the difficulties in setting become considerable and exposures unduly long, though crystals as small as 0·02 mm. have been handled with success. As to the aperture and plate distances, it is usually convenient to fix them in the neighbourhood of 4 cm., the extreme range being from 2 to 8 cm. For longer distances scattering and the long exposures necessary balance what little increase in accuracy is gained; for shorter distances the spots become far too crowded together. The best distance to use depends more than anything else on the dimensions of the crystal cell, and varies more or less directly with it.

Shapes of Spots with different Apertures and Crystals

Returning to the question of the shapes of spots due to different shapes of apertures and crystals; there are three chief types of aperture:

(α) Circular aperture.

(β) A short narrow slit parallel to the axis of rotation.

(γ) A short narrow slit perpendicular to the axis of rotation.

There are three types of crystal shapes met in practice:

(a) Approximately spherical.

(b) Flat thin plate which may be mounted in two positions: (b_1) with the rotation axis perpendicular to the plate; (b_2) with the rotation axis parallel to the plate.

(c) Short, needle-shaped crystals which may be mounted: (c_1) with the rotation axis parallel to the needle; (c_2) with the rotation axis perpendicular to the needle.

The shapes of the spots produced by the use of any of the types of aperture with any of the types of crystals can be derived in exactly the same way as in the case of a spherical crystal and aperture. Fig. 4 shows the theoretical size and shape of spots with a variety of such combinations. (The letters refer to the slit and crystal type used.)

It is obvious that if accurate values of ξ and ζ are required it is very useful to employ slits parallel or perpendicular to the axis respectively. The advantages of a slit over a circular aperture are exactly the same as they are in spectroscopy: a line of feeble intensity can be more easily detected, and its distance from a parallel line measured more accurately, than can be done for a spot of the same intensity. Instead of taking photographs with slits parallel and perpendicular to the axis successively, the two can be combined by using a cross-shaped slit.

The types (b_1), (c_1) give, with any shape of aperture, spots elongated along the ζ and ξ constant lines respectively. They therefore do not lend themselves to accurate measurements of ξ and ζ respectively. Luckily, such measurements are rarely necessary, as the shape of cell giving rise to these crystal shapes ensures that the ξ constant lines in the one case and the ζ constant lines in the other should be well separated. For both these types a circular aperture is best.

The type (b_2) has the disadvantage that different shaped spots occur for different orientations of the reflecting plane. Sharp lines parallel to the axis are produced when planes nearly parallel to the plane of the crystal plate are reflecting and diffuse spots (see Fig. 4, $\beta\, b'_2$), when planes nearly perpendicular to the plate are reflected. This is a serious obstacle to the estimation of relative intensity of spots, but, on the other hand, it is very useful as a help in identifying the indices of the spots. For this type a slit perpendicular to the axis is advantageous. The type (c_2) is similar in that the spots are different in shape for different orienta-

tions of the reflecting planes. Here they are almost circular when the needle is almost parallel to the emergent rays and are lines parallel to the equator ($\alpha c'_2$) when it is not. For this type a circular aperture is best.

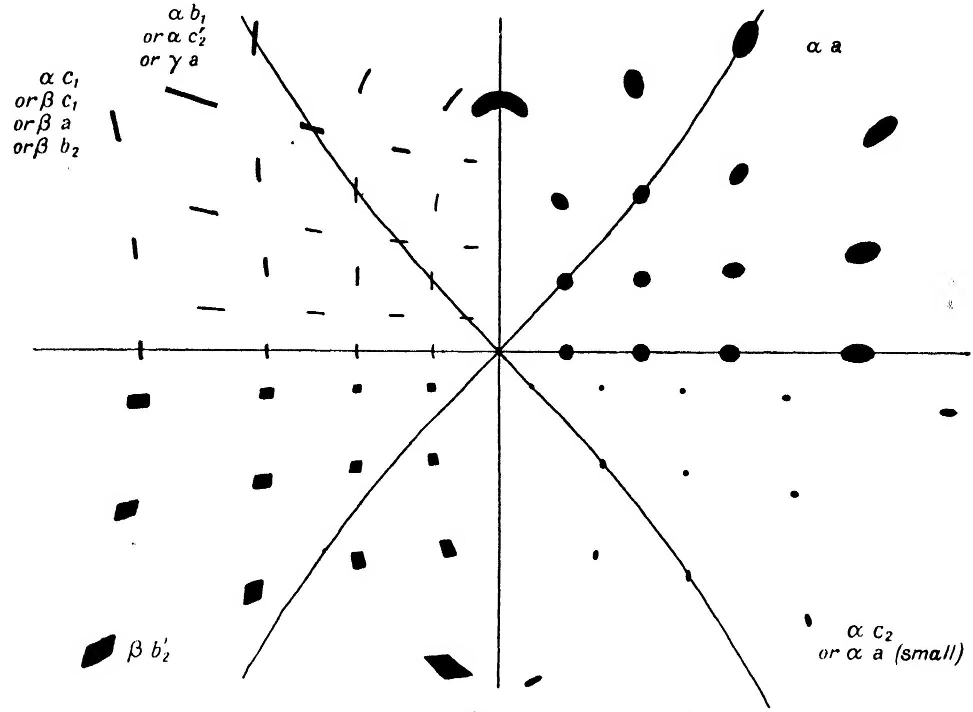


Fig. 4

X-Ray Beam Limited by Second Aperture

The second case of page 250, for which a second aperture (A_2) is used to cut down the area of the beam, will only be touched on here. It is the arrangement used in X-ray spectrometry and is fully dealt with in books on that subject. The object of this method is to obtain a very fine line reflection from a naturally or artificially produced face of the crystal either for making an exact measurement of the spacing of this plane, or, if this is known, of the wave-length of the incident beam. It is sometimes necessary in analysing a crystal to obtain a more accurate value of a spacing than an ordinary rotation photograph can give. For this purpose a rather larger crystal with a well developed or ground face 2 mm. or 3 mm. square is chosen and carefully mounted so that the axis of rotation lies in the face. If the crystal is not very absorbent a thin slip not more than 2 mm. thick must be cut or cleaved parallel to this face. The slit should now be one with solid block jaws or with two pairs of jaws about 2 cm. apart. The slit width for accurate work should not be greater than 0·05 mm. In order to make use of the so-called "focussing effect" the distance from slit to axis should be about the same as that from axis to plate. The crystal is oscillated through its reflecting position for one or more orders of reflection. If the crystal is thick and absorbent it can only be oscillated once on each side of the central beam. The difference between the lines on the plate does not in this case correspond to the true spacing unless the face is very accurately centred. To correct for this possibility of error two photographs must be taken with plates at different distances from the axis. If, however, the crystal is a thin slip the reverse position of oscillation (see Fig. 5) can be used as well, and the mean distance between the two pairs of lines on the plate used as their true distance. Conversely, the method described above

can be used for calibrating the plate if the spacing of the crystal and the wave-length is known. For this purpose either rock salt, calcite or gypsum can be used; mica, which gives finer lines than any of these, should only be used if its spacing has previously been determined, as it varies in different specimens from 9·8 to 10·1 A.U. Very much more accurate measures of spacing, 1 in 10,000, can be obtained in all cases in which the crystal is not too imperfect, by using the high order reflection where $\theta \rightarrow 90$ and the dispersion $\frac{dd}{d\theta} \rightarrow \infty$. With suitable calibration this method gives good results even where the apparatus is not of a precise type*.

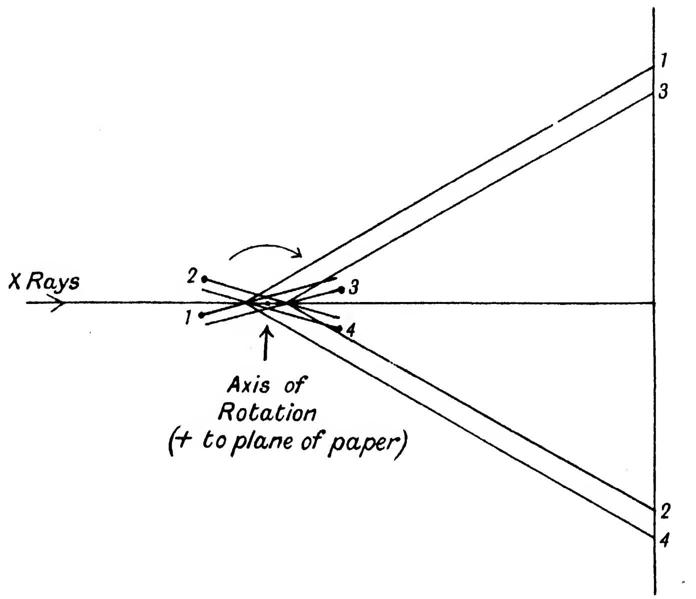


Fig. 5. The lines corresponding to successive positions 1, 2, 3, 4 of the crystal are numbered accordingly

(2) Axis of X-Ray Beam

We now pass to the second geometrical requirement of the rotation apparatus; that the axis of the incident beam must be perpendicular to the axis of rotation and must intersect it at the point where the crystal is placed. This requirement may best be taken into consideration together with (1). It will be noticed that the conditions (2) do not in themselves fix the direction of the incident beam. It may still lie anywhere through the equatorial plane in the crystal. It will be remembered, however, from section (1) that the control of the beam necessitated the possibility of varying the distance (b) from the aperture to the axis. This is best effected by moving the aperture and its adjustments along a fixed slide which is perpendicular to the axis of rotation. If, and only if, the axis of the beam is now adjusted to lie parallel to this slide, the motion of the apertures along it will make the axis of the beam continually intersect the crystal.

We can now see the types of adjustment and control necessary to an ideal aperture system:

(i) Motion of the whole aperture system along a direction perpendicular to the axis of rotation.

(ii) Small independent transverse motions of both apertures in order to bring the beam into the same plane as the axis and the direction of the slide. If the two apertures are

* Note (added in proof). The method often recommended of obtaining cell dimensions by measuring the distances between layer lines is very inaccurate and should only be used for rough work.

rigidly connected, as in a solid tube aperture or a block slit aperture, we require instead a small turning motion of the aperture system about a vertical axis and a small transverse motion of the whole system.

(iii) Small independent, vertical movements of the apertures in order to make the axis of the beam perpendicular to the axis of rotation, and at the right height to intersect the crystal; or, with the rigid aperture system, a small tilting motion about a transverse horizontal axis and a small vertical movement of the aperture system as a whole.

(iv) Some method of altering the width of slits and the diameter of apertures and preferably being able to change from one kind of adjustment to the other without loss of adjustments (ii) and (iii), which should if possible be made once and for all.

Of these adjustments, only (iii) is absolutely necessary. (i) can be dispensed with without loss of accuracy though it limits the range of the instrument and its convenience of working. (ii) may be corrected for by altering the adjustment of the plate (see p. 289). The absence

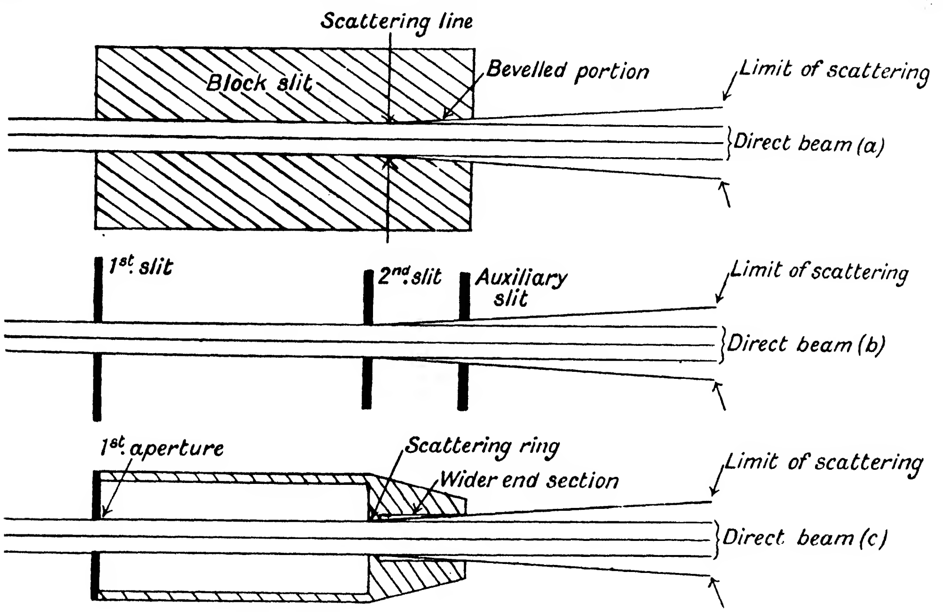


Fig. 6

of (iv) allows no variation in the accuracy of photographs. An additional refinement is an arrangement by which the slits can be adjusted to be accurately parallel or perpendicular to the axis of rotation.

Besides all these no aperture system can give good results unless precautions are taken to prevent X-rays scattered from the edge of the slit from fogging the plate. This is best done by bevelling the jaws of solid slits at a small angle, 5° or so, and opening circular apertures in the same way as shown in Fig. 6. The same effect can obviously be obtained by the use of three slits, the opening of the last slit being just greater than the last but one and therefore stopping only scattered radiation.

(3) Spindle and Crystal Holder

The third essential requirement of a rotation apparatus is the arrangement for holding and rotating the crystal. This need not be discussed here at any length, because it is essentially the same as in optical goniometry:

(i) A rigid axis mounted so as to turn freely.

(ii) Mechanism for giving this axis (*a*) a uniform rotation, and (*b*) a uniform rotation through some definite angle.

(iii) A goniometer head fitted with (*a*) two centering slides or other centering devices, and (*b*) two setting arcs.

(iv) Some optical means of adjusting planes to be parallel or perpendicular to the axis of the incident beam.

(i) The axis must be mounted in bearings that allow hardly any lateral movement, and at the same time must be more free to turn than in an optical goniometer: it must also have a greater resistance to wear. It is most important that the bearing should have no stiff region which will slow down the motion in one part of the rotation, and consequently give an entirely misleading intensity picture.

(ii) (*a*) A clockwork motor is probably the most convenient for this purpose. It should be capable of running for four or five hours, and of being rewound without shaking the apparatus. The motor should be geared so as to give the axis two or three revolutions per minute; a greater speed is unnecessary and may cause vibrations, a lesser speed is liable to a more serious disadvantage. If the number of complete revolutions in a single exposure is reduced to a few dozens, any intensity fluctuations in the X-ray tube may lead to changes in reflection intensities in one revolution which are not evened out in the successive ones. This caution applies more particularly if gas-filled tubes are used. It is inadvisable to have the axis directly coupled to the motor, as arrangements for limited angular rotations are more difficult to make. Instead of a clockwork motor, a geared down electric motor can sometimes be used to advantage; in fact any method of rotation can be used as long as it is strictly uniform.

(*b*) For rotations through a limited angle the "oscillation" method with cam and lever is probably the best. The cams must be accurately cut so as to give a uniform angular motion to the axis during each oscillation, otherwise no intensity measurements from plates taken in this way are of any value. If the intensity of the incident beam could be relied upon to keep constant better results could probably be obtained by allowing the axis to turn once or twice very slowly and uniformly through the required angle.

(iii) The head used for ordinary purposes is similar to those used in optical goniometry; it should be as compact as possible to enable the slit system and plate to be brought close (as near as 4 cm. or nearer) to the axis without fouling. For this purpose something in the nature of a Myers Stage Goniometer is indicated. The centering device is necessary to good working; if the double slide method is too cumbrous or expensive the two plate method can be used, in which the arcs are mounted on the upper of a pair of plane plates, the lower of which is fixed to the spindle and the two held together by a minute trace of grease: it is as accurate, but requires more skill in manipulating. The setting areas should be graduated and capable of being read to a fair degree of accuracy, not less than $\frac{1}{2}^\circ$; the range of angle should be about 30° each way. In the cases where the crystal is imperfectly developed a head with arcs of larger angle becomes necessary. Here we must compromise between accuracy and cumbrousness; arcs of 70° on each side and with an inner radius of 3 cm. are a convenient size.

(iv) The problem of setting the crystal optically may be solved in two ways. The rotation apparatus may itself be turned into a goniometer by the addition of a telescope and collimator, or the optical part may be quite separate. The first method is the more accurate, but it is necessarily the more cumbrous, while the second has the advantage of economy, particularly when it is employed in a laboratory where several rotation apparatus are in use; for here one goniometer does for all.

In the first case it is desirable to have the telescope or collimator geometrically interchangeable with the aperture system, so that both may be adjusted together. In this case if the telescope is made auto-collimating nothing further is required. Otherwise a fixed collimator at right angles to the principal plane may be used, or a collimator and telescope making equal angles with the principal plane. In apparatus not arranged for either of these

modes of setting, quite good results may be obtained by means of low-power microscopes which may be brought up in various positions.

There is one requirement of the rotation method that does not occur in ordinary goniometrical work. This is the setting of a crystal with the plane perpendicular to the axis of rotation. For this purpose the telescope and collimator may have an alternative position in a vertical plane above the crystal, or the head may be removable and made to rotate about a horizontal axis in front of the telescope and collimator of an ordinary goniometer.

(4) Plate or Film Holders

There are two chief forms of photographic recording used in the rotating method, the plate and the cylindrical camera. The necessary requirements of a plate holder are:

(1) The plate should be geometrically replaceable in the holder and the holder on the instrument.

(2) The holder should be capable of adjustment which will make the plate (*a*) parallel to the axis, (*b*) perpendicular to the incident beam.

(3) The distance of the plate surface from the axis should be capable of variation over a range of from 2 cm. to 8 cm. from the axis, and this distance should be exactly measurable.

Besides these, two other motions greatly extend the range of the apparatus:

(4) The plate should be capable, while remaining parallel to the axis, of making any given angle with the incident beam.

(5) The plate should be capable of being turned through 180° in its own plane about the normal to it from the crystal.

(1) This condition is essential to any comparison between one photograph and another, and if it is satisfied the adjustments can be made and the instrument calibrated for plate distance once and for all. The first requirement of the holder is therefore rigidity, and the second, that the plate should rest against the fixed metal part of the holder and be firmly held in position.

(2) The necessity for this adjustment should be too obvious to be insisted on, but it is sometimes thought that with good workmanship it can be dispensed with. If it is possible to make the holder so that the plate is within 3′ of being parallel to the axis and perpendicular to the incident beam, well and good. If not, some adjustment must be provided.

(3) This movement of the plate holder is best obtained by a slide and carriage, as on an optical bench. If the above requirements are satisfied it should not be difficult to measure the plate distance accurately. The plate, in any position of the plate holder, can be replaced by a blank and the distance from this to the axis measured directly. The simplest way which gives an accuracy of 0·1 mm. is to measure with calipers the minimum distance of contact between the axis shaft and the plate. A more accurate method, to within 0·02 mm., is to fix a pointer on the axis so that it just clears the plate; to remove the plate and measure the diameter of the circle traced out by the pointer by a reading microscope. Once the distance of the plate from the axis in a known position of the plate holder is determined, the instrument can be calibrated by means of a scale along the plate-holder slide. Instead of direct measurement, calibration with a known crystal and wave-length is often advised for fixing the plate distance. In the writer's opinion the direct way is more accurate; for while the accuracy of actual measurement is the same in both cases, the first method is free from all errors due to maladjustment of the crystal, accumulated errors of calculation, etc., that occur in the second.

(4) This degree of movement of the plate is useful for the measurement of small spacings for inorganic crystals, but it is not strictly necessary. The circle, on which the moving arm carrying the plate moves, should be able to be set within an accuracy of 5′.

(5) The function of the reversing arrangement (1) is to fix the position of the normal from the crystal to the plate, particularly when this is not marked by the central spot, *i.e.* when the plate is not perpendicular to the principal plane. By means of it the angle of reflection of any line on the plate can be calculated from the distance between this line and the corresponding line when the plate is reversed.

The requirements of the cylindrical camera are extremely simple. The film must be held firmly in position against a true cylinder whose axis coincides with the axis of rotation. These conditions are fulfilled in the camera described above. The only difficulty arises with the question of the estimation of the effective radius. The film is placed between two layers of black paper cut from the same piece. The inner diameter of the metal cylinder is measured, and also that of the cylinder with the film and black paper in position. The mean of these measurements gives the mean radius of the film. Obviously measurements of this kind are of a different order of accuracy than those with a plane plate; the thickness of the film itself being 0·3 mm. Here, therefore, calibration is more useful as it is at least as accurate, and further allows for the shrinking of the film on drying. As to the actual size of cylindrical cameras, 3 cm. is a convenient radius, with a height of 12 cm., which allows for the use of half-plate films. For more accurate work, where it is still desirable to use cylindrical cameras rather than plates, sections of a cylinder subtending any angle from 60° to 180° can be used instead of the plane holder on instruments which have a rotating plate arm.

In connection with the use of film cameras it is not necessary, as some writers suggest, to cut a hole through the film for the central beam; a cup-shaped piece of lead is as effective, and by removing it for a few seconds we have a sharp shadow of the crystal which can be used for measuring form.

This concludes Part II, containing the description of the apparatus and the discussion of its construction. Part III will contain a discussion of its adjustment and use.

A MAGNETICALLY OPERATED CIRCULATING PUMP FOR GASES.

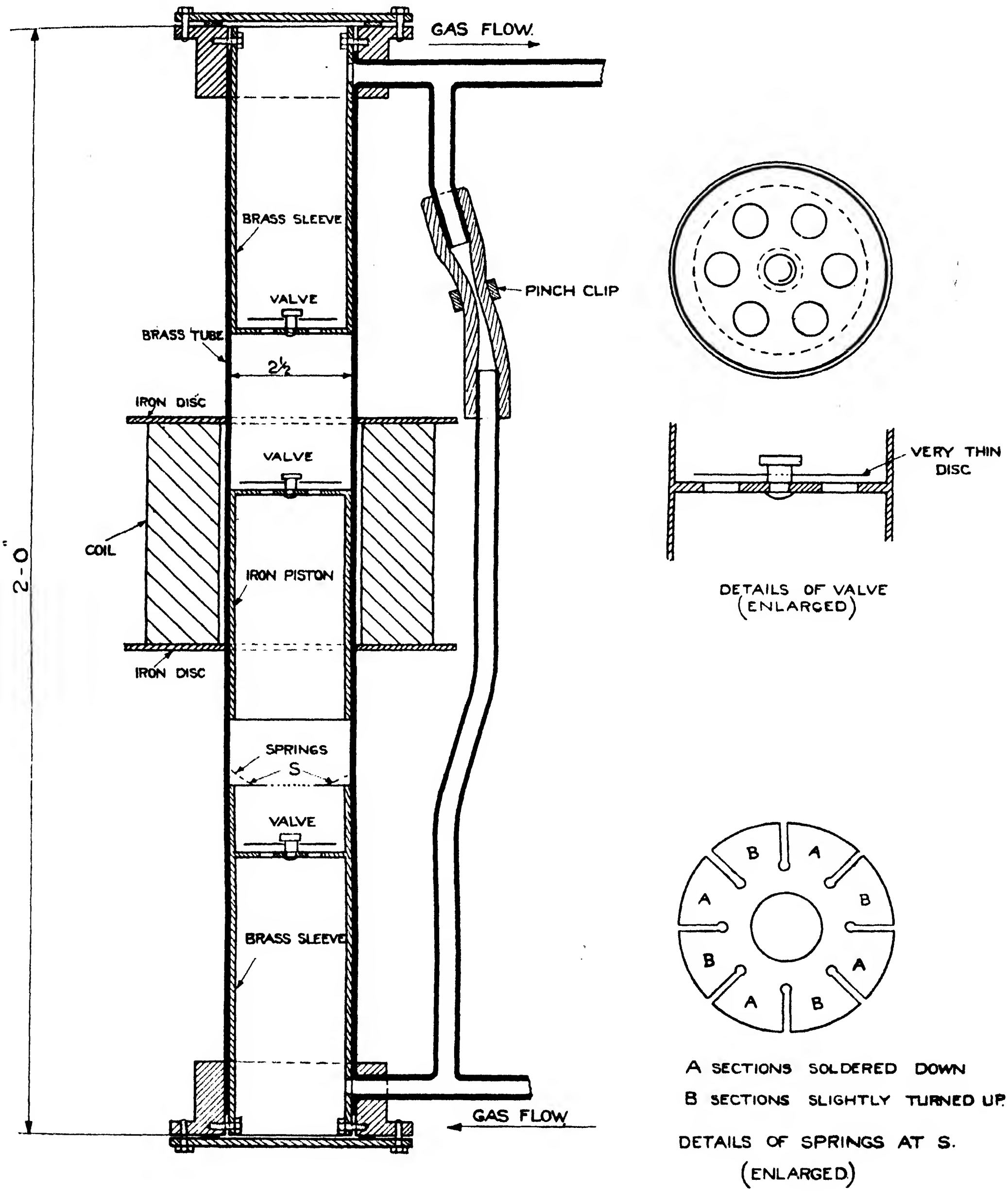
By FRANK ADCOCK, M.B.E., B.Sc. From the National Physical Laboratory.

[*MS. received, 29th June,* 1928.]

ABSTRACT. A description is given of a simple form of gas circulating pump designed so as to avoid risk of contaminating the gas with either oil or air. Motion is imparted to an iron piston by supplying an interrupted current to a solenoid which surrounds the upper part of the pump barrel. The pump has been used for circulating hydrogen at rates up to 30 cubic feet per hour.

EXPERIMENTAL research occasionally demands the circulation of considerable volumes of gas through apparatus without risk of contamination. Generally speaking, the mechanical pumps which are commercially obtainable in this country are unsuitable for this purpose, since the circulating gas is either brought into contact with oil or contaminated with air which may enter the pump by way of the bearings. A small diaphragm pump has been developed in France primarily for use with a refrigerating plant and is well adapted for the circulation of moderate quantities of gas without danger of contamination with oil or air. Since, however, this contrivance is designed for working at relatively high pressures any obstruction in the circulatory system may lead to an explosion in laboratory apparatus unless a suitable relief valve is provided.

The writer has found it possible to circulate hydrogen at rates up to 30 cubic feet per hour without contamination of the gas or risk of development of excessive pressures, by means of a simple form of magnetic pump. Essentially the pump consists of a brass tube



Magnetically operated circulating pump for gases

or barrel within which fits a light piston of iron or mild steel. The piston is quite unattached or "floating" and is capable of being drawn to the upper part of the pump barrel when an electric current is passed through a coil of insulated wire surrounding the tube.

During the actual working of the pump, an intermittent or interrupted current is employed, whereby the piston is alternately drawn upwards for a short distance and then

allowed to fall freely under gravity until the re-establishment of the current causes it to be drawn upwards again. The rapidity with which this cycle of operations is undergone naturally depends on the periodicity of the current supplied to the coil. On the upper part of the piston is carried a light disc valve arranged to close on the upward stroke and to open automatically by gas pressure when the piston falls. Two similar valves are incorporated in diaphragms fixed in the upper and lower parts of the pump tube so as to permit the passage of gas only in an upward direction. Only one of these latter valves is strictly necessary, but the presence of the second valve obviates any risk of a momentary reversal of gas flow in the circulatory system. The diagram gives some idea of the dimensions of the pump in use, but in the construction of similar apparatus it would probably be more expedient to be guided by the sizes of the tubes available for the pump barrel, piston, etc., rather than to work to some pre-determined dimensions. The long sleeves carrying the diaphragms and valves enable the holding screws to penetrate directly into the brass castings soldered to the ends of the pump barrel, a procedure which reduces risk of atmospheric leakage. Inspection covers are screwed to the "faced" castings at the top and bottom of the pump barrel, gas-tight joints being made by means of rubber rings.

The pump is intended for use with an electric supply of 110 volts and the coil is wound with 14 lbs. of No. 24 gauge double silk-covered copper wire. With this winding the coil bobbin becomes appreciably warm to touch after a run of several hours. A commutator, such as is used in small electric motors, is fitted for the purpose of interrupting the current supplied to the pump, and is conveniently rotated by means of an electric motor (say 1/25 H.P.) and a reduction gear. The periodicity of the pump is controlled by the speed of the commutator and the maximum pumping capacity appears to be attained when the piston makes about three complete alternations per second.

At high speeds the piston evidently moves only a short distance and at very low speeds the piston is dropped too far and tends to hammer on the springs at the bottom of the stroke. Changes in the effective rate of pumping are, therefore, best made, not by changing the speed of the pump but by varying the constriction in the by-pass tube (shown in diagram). An important factor in the working of the apparatus is the ratio of the durations of the "make" and "break," and the commutator is so arranged that the "break" in the current is only one-third the "make" in duration. Sparking at the commutator brushes is reduced by connecting a carbon filament lamp across the inductive winding of the coil and by shunting the "make and break" by a condenser of two or four microfarads capacity.

The circulation of gas, as against the use of a continuous stream from a cylinder or other source, has the advantage of reducing the amount of gas consumed—and in the use of such gases as argon or helium this is important. It also lessens the amount of impurity derived from the gas which may be absorbed by a substance exposed to it. Where a substance is treated by a continuous stream of fresh gas, even a minute amount of impurity in the latter accumulates in the substance absorbing it. Under circulation only one quantity of original impurity can be absorbed from the gas. If a reaction takes place—such as the reduction of an oxide and formation of water vapour—the reaction product (*i.e.* water) can be continuously removed by including a suitable absorption train in the circulating system. Gases as commercially available are always sufficiently impure to render the adoption of circulation advisable, and for this purpose the magnetic pump, which has already been in use for an aggregate period of over one hundred hours, is proving useful.

NEW INSTRUMENTS

THE AMSLER LONG-DISTANCE WATER-LEVEL RECORDER

THE Amsler Long-Distance Water-Level Recorder (Alfred J. Amsler and Co., Schaffhouse, Switzerland) is used to record continuously at a distance the height of the water in a lake, water-course, etc. It enables the oscillations of the water level to be followed over a long period of time.

The instrument consists of two separate parts, viz.:

(1) The *Transmitter*, which is set up near the open water—as for instance near an artificial lake—the level of which is to be recorded.

(2) The *Receiver*, installed at a distance, as for instance at a hydro-electric power station, or in an office.

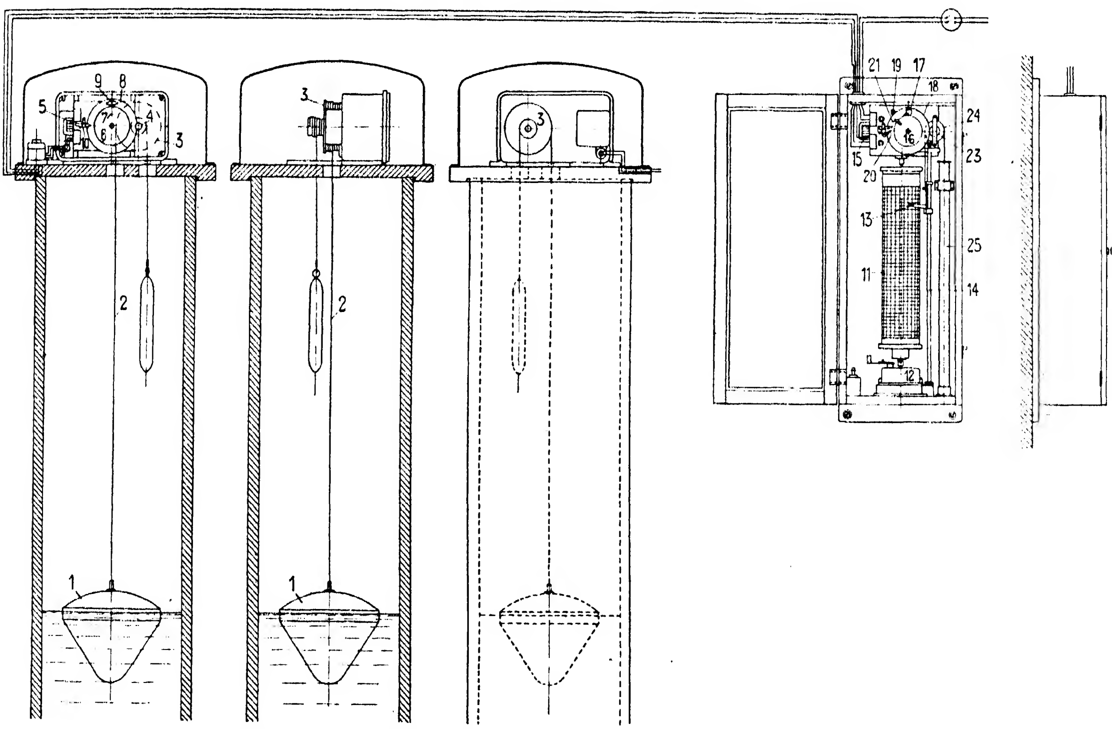


Fig. 1. Long distance water level recorder. Scale = about 1/20.

The transmission from the one to the other instrument is effected by single-phase A.C. of not more than 220 volts. Direct current cannot be used for the purpose. Two electric circuits are necessary to ensure a reliable and irreproachable transmission.

The transmitter (Figs. 1 and 2) consists in its main parts of a float 1 which is suspended from a thin wire rope 2 and actuates the long distance recording apparatus. This mechanism is composed of a small A.C. synchronous motor 5 which rotates at a uniform speed a disc 6 carrying on its edge a tooth-sector 7. Opposite to this and attached to the disc 8 is located a small planetary gear wheel 9 which at each rotation of the disc engages once into the toothed-sector 7, and interrupts for a short while the electric current to the receiving station. This planetary gear wheel 9 is not stationary, but alters its position along the edge of the disc 6 according to the movements of disc 8 to which it is attached. This disc 8 is in

gear with the small pinion 4 fixed to the axle of the rope drum, and rotates with the movement of the float. The position of the gear wheel 9 is thus governed by the rise or fall of the float, and the interruption of the electric current takes place at varying intervals during the rotation of the disc 6. The disc 6 makes one complete revolution every five minutes.

The receiver (Figs. 1 and 3) consists of a recording drum 11 actuated by clockwork 12, and a mechanism which lifts once in every five minutes with uniform speed a recording pen 13 along the recording drum. On reaching the top of the drum, the recording pen drops to the bottom again and immediately resumes its slow ascent.

At the instant the electric current at the sending station is interrupted, the recording pen 13, which does not, as a rule, touch the recording drum 11, is pressed by a slight turning of the guide 14, actuated by an electromagnet, on to the diagram paper and leaves on it a small mark.

The recording pen is raised by means of an A.C. synchronous motor 15 similar to the one fitted in the transmitter. The disc 6 of the transmitter, and the recording pen 13 of the receiver thus move at an exactly constant ratio. The small A.C. motor 15 rotates the disc 16, which carries with it, by means of the hook 17, the toothed disc 18. This latter is in

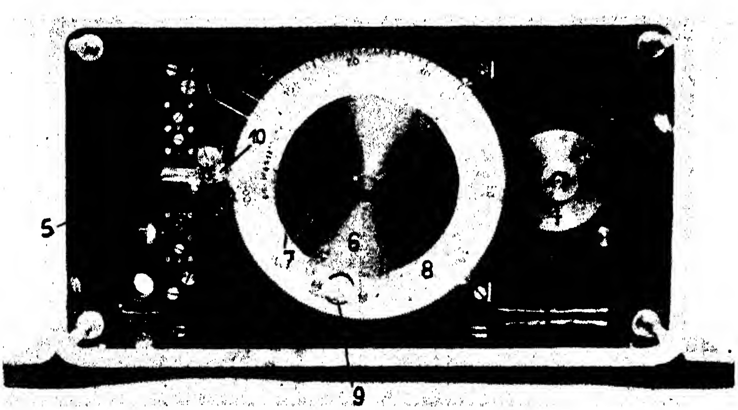


Fig. 2. Transmitting apparatus, the cover of the box having been removed.

gear with the pinion 23 fixed on the same axis as the winding drum 24 of the suspension wire of the recording pen 13. At every revolution of the disc 16, the hook 17 meets with a stop 19 which throws it over, thus disconnecting intermittently the toothed disc 18 from the carrier disc 16 only during the short time required for the drop of the recording pen. Afterwards the toothed disc 18 is again hooked to the carrier disc 16. The falling motion of the recording pen is damped by an air brake 25.

Previous to every new upward journey of the recording pen 13, an electric re-adjustment of the transmitter disc 6 takes place, caused by the interruption of an electric contact 20 which is reversed by the finger 21 fastened to the disc 16. Consequently an electromagnet fitted in the transmitter is excited, and readjusts the transmitter disc 6 by the attraction of its armature, thereby ensuring that the movements of disc 6 and recording pen 13 start simultaneously. The synchronisation is produced by means of the same electric circuit that actuates the recording pen of the receiver. The electric contacts used consist of the sealed glass tubes 10 and 20, filled partly with mercury and partly with nitrogen. They have a very long life.

The graphic record which is drawn by a pen filled with ink is composed of short perpendicular dashes about 1 mm. long, finally, however, appearing as a continuous thick line. The clockwork which rotates the recording drum must be wound up once a week. Normally

the recording drum has a height of 40 cm. (16 in.) and a diameter calculated to allow the paper to advance 1·7/8 in. (48 mm.) a day, or about 5/64 in. (2 mm.) per hour. It completes a revolution in 8 days.

The electric motors of the transmitter as well as receiver installations run synchronously to the number of cycles of the alternating current of the main to which they are attached. After a current-interruption they start automatically and attain their full speed within a few seconds. Every five minutes the long-distance recording mechanisms are synchronised, so that after interruptions, due to any cause whatever, as for instance to failure in the electric current, the recording is resumed within a few minutes.

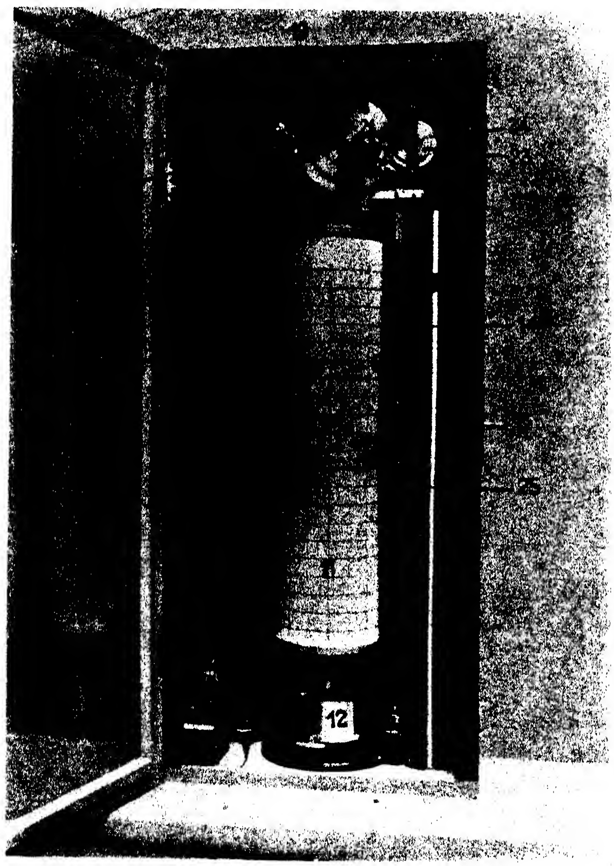


Fig. 3. Receiving apparatus.

The diagram is plotted to an exactness of about 1 mm. which means that in the case of reduction of 10 to 1 in the proportion of the water level to the diagram, the record would be marked to about 1 cm. accuracy.

The advantage of this system of long-distance recording over other known installations lies primarily in the fact that it is not the *changes* in the water level that are recorded, but the level of the water itself that is marked on the diagram. Trouble and defects in the transmission mechanism cannot therefore have any influence on the subsequent recordings. If an occasional fault should occur it will be sporadic and will not be continued in subsequent plottings. If the current is interrupted, the recording ceases, but resumes immediately the current is re-established.

LABORATORY AND WORKSHOP NOTES

ON THE MOUNTING OF WIRES IN STRING-ELECTROMETERS.

By WILLIAM CLARKSON, Ph.D., M.Sc. Physical Institute of the University of Utrecht.

In some recent work with a string-electrometer certain modifications of the usual technique in mounting the wires were made with, it is believed, an increase in speed and in reliability.*

In addition to the wire being central in the instrument and straight, it was of importance that the capacity of the electrometer should be reduced to a minimum; this meant minimising the capacity of the mounts and the lead.

The final form given to the mounts to which the wire was affixed is given in 2, X and Y. Pieces of glass capillary tubing of narrow bore, some 12 mm. long by rather less than 2 mm. diameter, were drawn; these dimensions were not arbitrary but were determined

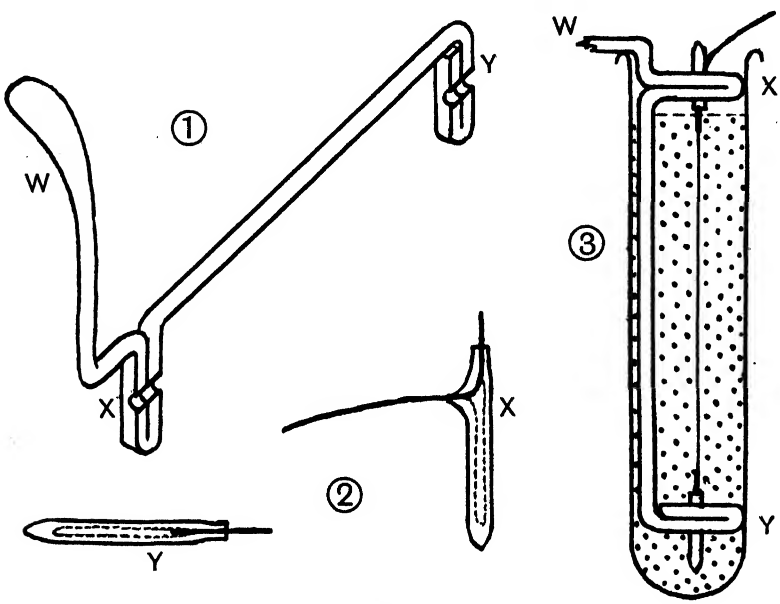


Fig. 1

by those of the receiving hole in the amber mounts. In one of these tubes (the lower X), a side hole some 2 mm. from the end, was blown. A pin-hole gas jet proved suitable. Pieces of 0·1 mm. wire (copper generally) were now inserted, as shown, and fixed by fusing the glass. The other ends of the tube were then drawn off. The wire in X was made of minimum length if contact was to be made internally, or long enough to pass to the outside of the instrument case where external contact was to be employed, as indeed was the usual case here.

For the actual mounting of the wire an aluminium frame of squared 2 mm. wire was made (see 1). The distance XY was made equal to that between the amber mounts in the instrument in their final position, here 11 cm., and X and Y were as large (here approx. 2 cm.) as would still permit the frame to fit freely in a convenient test-tube (see 3). Semi-cylindrical grooves were cut in X and Y of a size enabling the glass mounts to be fitted in

* Clarkson. *Phil. Mag.* 6 (1927) 312.

them firmly with a minimum amount of de Khotinsky cement. Care was taken in fixing to see that the glass mounts were so oriented that they would slide freely into the amber mounts; this was, approximately axially.

The Wollaston wire was now somewhat tautly stretched between the wire pieces and soldered, resin being used as flux. With the joint at *Y* touched with a little molten paraffin wax the whole system up to just short of *X* could be immersed with saftey in a test-tube of nitric acid (see 3), for only the wire coating was soluble. On solution being complete the system was transferred by the handle *W* to a similar tube of alcohol, and then, as required to the instrument, the wire, being taut in a rigid frame, being as safe as possible. All parts were now made fast and the mounts freed from the frame (*X* first) by heating the latter at the ends of *X* and *Y* with the tip of a hot metal rod.

Before mounting it was necessary to screw the amber mount for *Y* up as far as possible so that later the wire could be slackened sufficiently for the maximum sensitivity to be attained. It was found that on a wire being broken a new wire (say 1 to 5 μ) could be inserted and a preliminary calibration made in 20 minutes. Failures were rare.

One suggestion with regard to the mountings employed for wires may be made. If the electrometer case had stopped short at the level of the lowest amber, which could have projected through the bottom, the wire of *X* could have been continued through the glass and the amber, and all the convenience of external contact gained without increase of the capacity. Alternatively perhaps the amber itself could have been removable and have replaced the glass altogether. Such a scheme is quite feasible.

A MOTORLESS CIRCULATOR FOR LIQUIDS.

By CHARLES RECORD. The Technical College, Huddersfield.

THE apparatus illustrated (in three forms) has been devised by the writer for continuously circulating or agitating liquids without the use of a motor or moving parts; the power being supplied by an ordinary water jet pump.

The tubes *B* and *C* are placed in the liquid to be circulated, the end of *B* being lower than that of *C*. On aspirating through *D*, by means of the pump, the liquid rises in *B* and *C* till its surface in the vessel is lowered to the bottom of *C*, the chamber *A* being partly filled. Air then enters through *C*, and continues to carry liquid up with it, the liquid returning down *B*. Liquids may easily be raised several feet to the chamber *A*.

Fig. 1 shows a generally useful form made in glass, *B* being connected to any apparatus through which the liquid is to circulate before returning to its source. The form shown in Fig. 2, while rather less efficient than the former, was suggested by Mr F. Hobson, of Huddersfield Technical College, as more suitable for circulating liquids which froth, as in the first form froth may suck into the pump, resulting in a slight loss of liquid. Fig. 3 shows a form which can be put together in a few minutes without glass blowing, or can be made in metal, and which is more suitable than the other forms for circulating any liquid containing solid matter which is liable to choke the circulator, as it can be readily opened for cleaning. The tube *D* is hooked at the top so that liquid ejected from *C* shall not fall into it. The tube *B* is only made in one straight piece, as shown in Figs. 2 and 3, when the apparatus is required for agitation only. For this purpose it can be got into vessels where there is no room for the usual motor driven stirrer.

If the tubes *B* and *C* are of equal bore the action is intermittent, the chamber alternately filling and emptying. This is satisfactory for agitation, but not efficient for one-way circulation; but if *C* has a bore of 8 or 10 mm., and *B* 5 or 6 mm., perfect one-way circulation is obtained, the level of the liquid in *A* remaining constant. The chamber may of course

be of any size, and, if large, will hold a reserve of liquid and automatically maintain a constant level in the vessel from which the liquid is circulated. Evaporation by the air

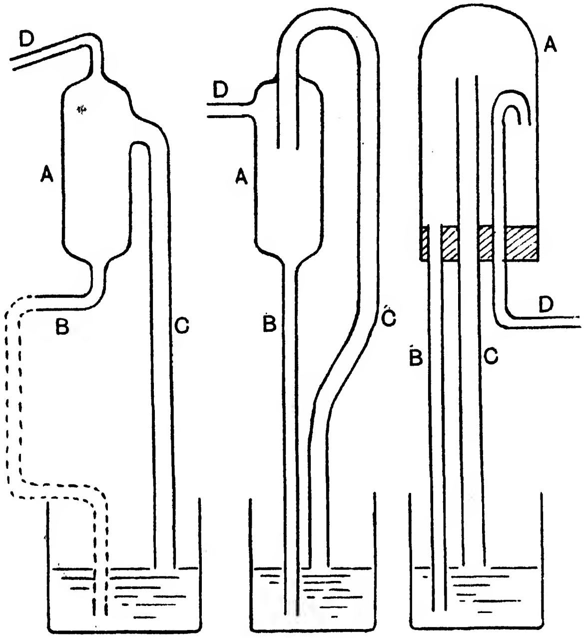


Fig. 1 Fig. 2 Fig. 3

pumped through may be prevented, if necessary, by arranging for the air supply to bubble through similar liquid before reaching the surface of that circulated, but for most purposes this evaporation is, of course, negligible.

RECENT RESEARCHES AT THE NATIONAL PHYSICAL LABORATORY

The National Physical Laboratory. Report for the Year 1927. Pp. vi + 264. London: H.M. Stationery Office. Price 7*s.* 6*d.* net.

(*Continued from page* 265.)

AERODYNAMICS DEPARTMENT

During the past year all the wind tunnels of the Department have been in constant use, and in addition the new whirling arm has become a permanent part of the equipment with a programme of research which will occupy at least the whole of the coming year. Of the longer researches mentioned in the last Report, those on the autogyro and on the high-speed aeroplanes have been completed as far as wind tunnel tests are concerned, but there remains a considerable amount of work to be done in analysing the results before comprehensive reports can be prepared. It is particularly gratifying to note that a very considerable improvement in the seaplanes which competed successfully for the Schneider Cup was rendered possible by the research on models of these machines in the Duplex wind tunnel, and that as a result of this work attention has been strongly focussed on the necessity for further research on the problem of drag reduction as a means of improving the performance of future aircraft.

The research on heat convection from an aerofoil surface has proved exceedingly difficult, and a few further experiments are still required before the final results can be published. The problem

of wing flutter has occupied a four-foot tunnel during practically the whole year, and the investigation has now reached a definite stage, in that the whole of the aerodynamic derivatives involved have been obtained for one form of wing and aileron. A full account of this work appears later in the Report. Work on the fluid flow behind bodies of high resistance, directed originally to the elucidation of the problem of the stalled aerofoil, has been continued during the year, and many new and interesting features of the fluid motion behind several forms of such bodies have been revealed. Researches have been initiated on the nature of the interference effects of the various component parts of aircraft, including a more complete study of the particular problem of airscrew-body interaction, the ultimate object being the provision of data which will enable designers to improve the overall efficiency of their machines. Work on slotted wings, with and without flaps, has been continued and has yielded some interesting results. Further research on the effect of slots on low-speed control has been commenced, mainly as a result of the recent Air Ministry decision to use automatic slots of the Handley Page type on a large number of service machines. The details of this work cannot usefully be summarized and reference should be made to the Report itself.

METALLURGY DEPARTMENT

Preparation of pure iron. Work on the production and properties of pure iron has been continued during 1927. It has been found possible to produce extremely pure iron, containing only a trace of phosphorus, by the use of anodes of a high degree of purity and by modifying the conditions of electro-deposition. The deposited iron, after annealing in hydrogen, can be rolled into sheet form. Magnetic tests carried out on stampings from the rolled sheet produced in this way show that, whereas the deposited iron is superior in its magnetic properties to commercial silicon iron, it is markedly inferior to the material obtained by melting the electrolytic iron.

Single Crystals. Considerable progress has been made during the year in developing the technique for the production of single crystals by the method which has been principally used by Bridgeman. Single crystals of copper, zinc and antimony have been prepared by this method for use in the joint research with the Engineering Department on fatigue. In addition, large single crystals of copper and bismuth have been provided for the determination of their thermal constants in the Physics Department of the Laboratory. The conditions affecting the formation of single crystals have been studied, in order to place the method of production on a more satisfactory basis, particularly as it is now desirable to produce crystals of much larger dimensions than were hitherto required. Efforts have also been made to produce single crystals by recrystallization methods, operating entirely with solid materials, as distinct from crystallization from the molten state. The methods investigated differ from those of Carpenter and Elam in that, instead of utilizing the recrystallization of cold-worked material, they depend upon such transformations as the allotropic change of iron from the α to the γ state. The production of considerable lengths of rod or wire of iron and nickel in the form of single crystals is very desirable for the purpose of the research which is in hand on the relation of magneto-striction to elastic hysteresis.

New Alloys. Work has been begun to explore the possibility of finding an alloy or groups of alloys presenting mechanical properties, particularly in the wrought state, superior to those of existing commercial alloys. The anticipation of such improved mechanical properties is derived from the fact that certain alloys of aluminium with zinc and copper attain considerably higher degrees of strength than alloys of the duralumin type. Although these particular high-strength alloys suffer from certain disadvantages, they at any rate serve to show that aluminium alloys of very high strength can be produced.

Solders. The comparative study of the effects of prolonged loading upon the zinc-cadmium and lead-tin solders referred to in the last Report has been continued. The results are of interest in showing that lead-tin solder is capable of sustaining only very light loads without deformation, whereas the zinc-cadmium solder can maintain considerably greater loads. This difference between the two types of solder is greater than is indicated by the comparison of ordinary tensile test results.

Iron-chromium Alloys. In regard to the production of iron-chromium alloys, a series containing up to about 30 per cent. of chromium had in the past been prepared free from oxide. An attempt to anneal these alloys in an atmosphere of argon led to contamination of the specimens with nitrogen. It is unfortunately essential to anneal these alloys at a very high temperature in order to secure by diffusion that uniformity of composition which is required to render the material satisfactory for thermal and microscopic investigation. By means of the high-frequency furnace it has become

possible to anneal a series of alloys varying from 0 to 26 per cent. of chromium at about 1300° C. *in vacuo*, instead of in an atmosphere of argon or other gas. Under the usual conditions of the induction furnace different specimens would be liable to assume different temperatures.

In order to avoid this possibility, all the samples are enclosed in a short tube made of a pure variety of commercial iron, the interior of the tube and the specimens being coated with alumina to prevent any risk of welding at the points of contact. The iron tube containing the samples is then suitably lagged and placed inside a larger silica tube, which can be maintained in an evacuated condition during the annealing operation by means of a mercury diffusion pump and subsidiary equipment. It has been found possible to maintain the pressure as low as 0·02 to 0·01 mm. of mercury when the tube and samples are held at 1350° C. The pressure in the cold tube, both before and after the annealing process, can readily be reduced to 0·003 mm., suggesting that a large amount of gas has been extracted from the metal or the refractories or both at the high temperature. In this case, it may be noted, the question of leakage of gas through the silica containing-tube does not arise, since the temperature of this tube does not become sufficiently high to involve any risk of porosity. The samples annealed *in vacuo* in this manner proved to be extraordinarily soft compared with those previously prepared, but one or two specimens showed traces of impurity under the microscope. The thermal investigation of these alloys over the temperature range below 1000° C. has been undertaken.

Dental amalgams. A series of experiments has been made with the object of obtaining a general survey of the process of setting in dental amalgams. Microscopic examination at various intervals of time, of amalgams prepared by trituration of filings of silver-tin alloys with mercury, showed that although hardening had proceeded a considerable way toward completion after 24 hours from the time of mixing, microstructural equilibrium had not been attained even after 12 months. The effects of varying the proportion of mercury to filings and also of heating the amalgams to various temperatures have been studied, with the result that definite indications have been obtained that one or possibly two intermetallic reactions take place during the process of setting.

In a paper published by Stock in Germany, in April 1926, dealing with toxic effects of mercury vapour, it was suggested that there was a serious risk of mercury poisoning resulting from the presence of amalgams in the mouth as dental fillings. At the request of the Dental Investigation Committee the data given by Stock are being checked by determining the loss of mercury by volatilization when a stream of air at the temperature of the mouth is aspirated over dental fillings. For this purpose tests are being made in the Dental Department of Guy's Hospital on teeth into which amalgam fillings have been inserted.

Die-Casting. The work on die-casting during the past year has principally been concerned with the development and construction of an apparatus for the production of die-castings under pressure: it is proposed to apply pressure to the molten alloy for the purpose of studying its effect on the properties of the castings produced, including their soundness, strength, and accuracy of dimensions. In addition to this an investigation into hot shortness and the relative behaviour of various die-casting alloys in this respect has been carried out.

It is well known that at high temperatures aluminium alloys in the cast state lack toughness, and readily fracture under a blow, or through stresses produced in the process of solidification and contraction in the mould before stripping or during stripping. In many cases the weakness is exhibited by the ease with which headers and runners can be knocked off the castings whilst hot; in other cases, *e.g.* in silicon-aluminium alloys, it is difficult to do this without distorting the castings. The relative behaviour of alloys in respect to this weakness, or hot shortness, is of great importance as regards the facility with which castings can be produced. Very little published information bearing on the question exists. In the Laboratory experiments, the energy absorbed in fracturing cast test-bars at a series of temperatures up to the commencement of melting (solidus) has been measured for commonly used die-casting alloys by means of a special Charpy machine. The results have been incorporated in a report to the British Non-Ferrous Metals Research Association.

Thermo-Couples. Special attention has been given during the year to the thermo-couples used in temperature measurement in the Department. The alloy arm of the standard couples now employed consists of an alloy of platinum with 10 per cent. of rhodium. For use at very high temperatures, however, thermo-couples the arms of which contain 5 and 20 per cent. of rhodium respectively are in use, as it has been found that these alloys are less easily contaminated than pure platinum under these extreme conditions.

Electric Resistance Furnaces. The "Silit" furnaces have been in continuous operation and are proving very useful. An entirely different type of resistance heater has, however, been developed in the Department during the year. This depends upon the contact resistance between a succession of graphite or carbon pellets or discs contained in a refractory and approximately gas-tight sheath. It is found that, when used in this manner, the carbon pellets remain unchanged for a very long time even when heated to temperatures as high as 1500° C. The temperature attainable by means of these heaters is limited only by the power of the refractory sheath to withstand the heat developed. Experimental models of these furnaces have proved highly successful and it is expected to put them into regular use very shortly. The use of these heaters is applicable both to large and small furnaces, and to other purposes where a high-temperature heater of great durability and low cost is desirable. R. T. B.

(*Concluded*)

REVIEWS

The Thomas Recording Gas Calorimeter. Fuel Research Technical Paper No. 20, Department of Scientific and Industrial Research: H.M. Stationery Office, Adastral House, Kingsway. Pp. vi + 42. Price 9*d*. net.

This pamphlet consists of an interesting account of the investigation carried out at H.M. Fuel Research Station into the recording gas calorimeter designed by Professor C. C. Thomas, of Wisconsin. The heat developed by the combustion of the gas is abstracted from the combustion products by a stream of air whose rise in temperature is a measure of the calorific value. The gas flow, combustion air supply and cooling air supply are controlled by three separate revolving drum meters geared together, so that changes of speed affect the temperature rise only to a secondary extent. Resistance thermometers constructed of grids of nickel wire and placed across the stream of cooling air measure the increase of temperature. They are placed differentially in a Wheatstone's bridge which is automatically balanced by the action of the galvanometer, and a continuous record of the balancing resistance is obtained. The instrument in some respects is a development of the Thomas Gas Flowmeter described in the *Journal of Scientific Instruments*, September, 1927.

It is difficult to see what advantages are gained by using air as the cooling medium instead of water. The arrangements are ingenious and it is stated that the calorific value of a gas, if constant, can be measured by the instrument in its final form to 1 B.Th.U. per cu. ft., *i.e.* to 1 part in 500. Where the calorific value fluctuates, there is a large lag in the readings and the amplitude of periodic variations, as measured, may be considerably less than the true variation, although the mean reading may be correct. The interest of the narrative, however, for the general reader lies in the record of the errors which were found and eliminated. The original instrument was made by the Cutler Hammer Company of New York, and various defects, mainly in the recording mechanism, were found. The Cambridge Instrument Company, as the English agents, then re-designed certain portions of the instrument and were successful in remedying most of these defects. The tests which revealed the original faults, and the steps taken to remove them, are all given in the report, whose value is greatly enhanced thereby, and any experimentalist who has to deal with apparatus of a similar character, or with galvanometer recorders, will find much to interest him. H. M.

Commercial Electrical Measuring Instruments. By R. M. Archer, B.Sc. (Hons.) Lond., A.R.C.Sc., M.I.E.E. Pp. xvi + 260. London: Sir Isaac Pitman and Sons, Ltd. Price 10*s*. 6*d*. net.

If we understand the purpose of this book correctly, it is to describe the internal structure and mode of action of indicating instruments, such as are usually employed in everyday commercial electrical measurements, for the information of those who have only an elementary knowledge of electrical work, or may be classed as partially skilled assistants. If this interpretation is correct, then we can say that the author has succeeded. The book deals apparently with those instruments with which he has had laboratory acquaintance, but we fear it is not sufficiently broad to have any appeal to the designer, manufacturer, or advanced experimentalist.

The treatment of some of the sections is somewhat inadequate. This is notably the case in

dealing with Wattmeters, Induction pattern instruments, Recorders, and Radio measuring devices, and is probably the inevitable result of endeavouring to produce an elementary book on a highly specialized and very detailed subject. The arrangement of the subject matter also requires some revision. For instance, the expansion type of Hot Wire instrument is dealt with, but it is not until more than one hundred pages later that we find any mention of the Thermo junction type of instrument, and then only a single type is considered for radio frequency measurements; and it is immediately followed by descriptions of special patterns of instruments which are based on principles treated in the earlier pages of the book and have nothing to do with high frequency measurement. What may be the special purpose of Articles 123 and 124 on p. 237 it is difficult to understand; and again, why does the short note on "Nomag" cast iron find a place at the end of Chapter XIV, after a paragraph on typical data for dynamometer instruments?

Although the author states in the preface that his aim is to explain principles rather than mechanical details, we find him persistently deviating from his set course, and then the information becomes rather disjointed and incomplete and not always representative. As an elementary work the book would have been greatly improved had the principles been more broadly and fully treated, and a greater number of numerical examples included, which would have given the reader a better idea of the magnitude of the quantities under discussion. Some information on the care and use of instruments, together with detailed information on the experimental methods of investigating the performance and errors of the instruments described, would have added considerably to the value of the book.

The illustrations are in general clear and well drawn; but we take exception to Fig. 12, which is very misleading. The bibliography, with which the book concludes covers only three publications, and it is very questionable whether an elementary student should be referred to many of the specialized papers mentioned in it. A. C. J.

CATALOGUES

MESSRS WATSON & SONS (ELECTRO-MEDICAL) LTD., Sunic House, 43–47, Parker Street, Kingsway, London, W.C. 2, will send to any reader, on application, their new catalogue of Electro-Medical Apparatus. Messrs Watson are well known as makers of X-ray apparatus for medical purposes. The new catalogue indicates that they supply also an extensive range of general electro-medical apparatus, and gives particulars of a variety of appliances for current supply for therapeutic purposes, heat and ultra-violet radiators and many instruments and accessories for special purposes.

MESSRS H. W. SULLIVAN, LTD., Leo Street, Peckham, London, S.E. 15, send two new catalogues which contain descriptions of many new instruments and should be of considerable interest to electrical readers. The first of these, entitled "Precision Alternating Current Measuring Apparatus for High Frequencies," gives particulars of power sources, including valve oscillators for a variety of frequencies; non-reactive resistances, including ratio arms, rheostats, slide and fixed value resistances; mica condensers, capacity test sets and detectors. The second, entitled "Laboratory Air Condensers for all Frequencies," is prefaced by some interesting notes on the properties of variable air condensers as an aid to their selection. Part I of this list, Laboratory Variable Condensers, includes the Sullivan-Griffiths precision variable condenser, silica-quartz condensers and a number of other types; Part II describes Laboratory Fixed Air Condensers of the silica-quartz and other patterns.

Messrs Sullivan send also their catalogue of Precision Direct-current Measuring Apparatus.

MESSRS ADAM HILGER, LTD., 24, Rochester Place, Camden Road, London, N.W. 1, have issued, in the form of an eight page pamphlet, a bibliography, selected by Dr Wallace R. Brode, of Recent Work on Absorption Spectrography.

THE CAMBRIDGE INSTRUMENT COMPANY, LTD., 45, Grosvenor Place, London, S.W. 1, as the manufacturers of the Thomas Recording Gas Calorimeter for the accurate measurement of the calorific value of gas, inform us that the Gas Referees, after tests on one of the latest instruments, are prepared to prescribe the calorimeter for use in official testings. Official tests on the instrument are described in Fuel Research Technical Paper No. 20 of the Department of Scientific and Industrial Research, which is reviewed elsewhere in this issue.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V | OCTOBER, 1928 | NO. 10

THE ERRORS ASSOCIATED WITH HIGH RESISTANCES IN ALTERNATING CURRENT MEASUREMENTS.

By R. DAVIS, M.Sc. Of The National Physical Laboratory.

[*MS. received*, *25th May*, 1928.]

ABSTRACT. (1) Some of the properties of a resistance which is shielded at a known potential have been investigated. (2) The effect of adding a number of these units in series, to form a high voltage resistor, has been considered, and expressions for the phase angle at the low and high voltage ends of the resistor have been derived. (3) A method for determining the characteristics of a unit has been described, in terms of which, and the number of units, these phase angles are expressed. (4) Some of the practical limitations which may manifest themselves in the designing of a shielded resistor have been discussed.

(1) INTRODUCTION

IN this paper it is proposed to deal with the properties of high resistances for use in electrical measurements at high voltages. Hartshorn (*World Power*, October, 1927) has given an account of the properties of ordinary "non-inductive" resistances, and has dealt with the shielding of resistances for use with high voltages.

In the determination of the characteristics of voltage transformers, high resistances are required to take the full primary voltage, while a fraction of the voltage drop at the earthed end of the resistor is compared with a known fraction of the secondary voltage. The fraction of the primary voltage which is used is the product of a small fraction of the total resistance and the current through that small resistance. This current may not be in phase with the total voltage across the resistor, with the result that error is introduced into the phase angle determination of the voltage transformer. In addition, the current flowing through this fraction of the resistance may not be the same as the quotient of the total voltage across the resistor and the total resistance in the resistor, with the result that the ratio determination might also be in error.

The determination of the power factor of cable dielectrics requires the measurement of a small angle which may be of the order of 0·0050 radian. This angle, which represents the deviation from exact quadrature of the current through the cable dielectric, and the voltage across it, can be determined by means of a dynamometer wattmeter, used in conjunction with a resistor to withstand the voltage applied to the dielectric. In this measurement errors comparable in size with the quantity being measured may be introduced by the resistor.

A common current rating for a high resistance is 1/20 ampere, so that the resistance required per 100 volts or per 110 volts is 2000 ohms, and for a test on a voltage transformer rated at 33,000/110 a resistor of the value of 600,000 ohms might be used. The errors associated with resistances of this order are due chiefly to the capacity of the windings to

surrounding objects. When a voltage is applied to the resistor, current passes from the different points of the resistor to these surrounding objects which are generally at earth potential. Consequently the current in the resistor is changing along its whole length, both in magnitude and in phase. If the phase angle of the resistor at any point be defined as the angle between the current in the resistor at that point and the voltage across the whole resistor, then this phase angle will vary along the resistor.

It will be shown below that in the case of a resistor R having a capacity C uniformly distributed to earth, the phase angle at the earthed end of the resistor is $-RC\omega/6$, where ω is $2\pi \times$ frequency. The negative sign indicates that the current at the earthed end of the resistor lags behind the voltage across it.

In the case of a resistor having a resistance of 600,000 ohms which has been used for voltage transformer measurements, the capacity to earth of the windings was estimated to be of the order of 300 micromicrofarads, so that the error introduced into the phase angle determination of the voltage transformer at a frequency of 50 cycles per second by the resistor, if not corrected for, would be $\frac{600,000 \times 300 \times 314}{10^{12} \times 6} = 0{\cdot}0094$ radian or 30 minutes, an error which might be greater than the actual phase angle of the voltage transformer. Similarly, if this resistor were used in the determination of the power factor of a 33,000 volt cable, the error introduced by it would be 0·0094, and the correct value of the power factor of the cable might be of the order of 0·01, so that the error would be comparable with the quantity measured. In one method of measuring the power factor of three-phase cables the measuring instrument, generally a dynamometer wattmeter, is maintained at high voltage, the high voltage end of the resistor being connected to the pressure coil of the wattmeter. In this case the error introduced by the resistor is due to the phase angle at the high voltage end of the resistor. This angle is $+RC\omega/3$ as will be shown later, where the positive sign indicates that the current at the high voltage end of the resistor is in advance of the voltage across it. The error introduced into the measurement of the power factor of one of the phases of a three-phase cable dielectric, when this resistor of 600,000 ohms is employed, would be 0·0188, *i.e.* twice the error of the previous case cited. The errors introduced into these measurements through the changes in magnitude of the current in the resistor are much less serious, and their effect can be neglected at this stage.

By dividing these resistances into sections, and enclosing each section in shielding cases maintained at a definite potential with reference to the potential drop in the unit being shielded, the errors due to earth capacity can be considerably reduced. Orlich and Schultze* and Silsbee† have described resistors designed on this principle.

In what follows, one section of a resistor is considered together with its shield. The effect of the screen potential on the phase angle at a point in the section is determined. Then the effect of adding units in series is considered, and an expression is obtained for the phase angle at the earthed end of a resistor consisting of a number of unit sections. Finally from certain measurements which can be made on any one unit, an expression for the phase angle at the earthed end of a resistor is given in terms of these measurements, and the number of units constituting the resistor.

(2) Unit Shielded at a Known Potential

Let R (Fig. 1) be the resistance of a section, and let it have a uniformly distributed capacity C to the screen. Let V_1 be the voltage applied to the section and let the potential of the screen be P. Let the resistance between X, at a distance x from the earthed end of R, and E, be Rx.

* *Archiv für Elektrotechnik* (1 Band, 1912).

† Scientific Papers of the Bureau of Standards, No. 516.

Let $Rx/R = K$ so that $d\,Rx = R\,dk$, and the amount of capacity associated with $d\,Rx$ equals $C\,dk$.

If v be the voltage at X, and i the current in the resistor at this point,

$$di = j\omega C\,(v - P)\,dk,$$
$$dv = Ri\,dk,$$

where j is the vector operator rotating through 90 degrees and $\omega = 2\pi \times$ frequency.

From these equations we get the relation

$$\frac{d^2v}{dk^2} = R\frac{di}{dk} = j\omega CR\,(v - P).$$

The complete solution of this equation is

$$v = Ae^{ak} + Be^{-ak} + P,$$

where A and B are constants and

$$a = \sqrt{j\omega CR}.$$

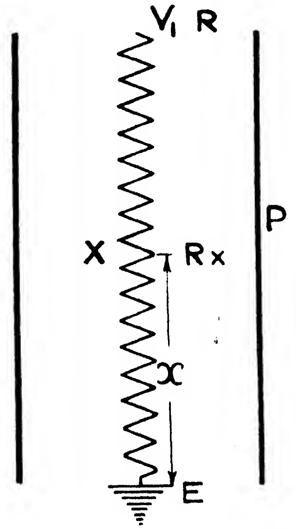


Fig. 1

To evaluate these constants we put

$$v = V_1 \quad \text{when} \quad K = 1$$

and

$$v = 0 \quad \text{when} \quad K = 0.$$

The equation then becomes

$$v = \frac{e^{ak}\,[V_1 - P\,(1 - e^{-a})] - e^{-ak}\,[V_1 - P\,(1 - e^{a})]}{e^{a} - e^{-a}} + P \qquad \ldots\ldots(1).$$

The current i at any point is given by the equation

$$i = \frac{1}{R}\frac{dv}{dk},$$

$$= \frac{1}{R}\frac{a}{(e^{a} - e^{-a})}\{e^{ak}\,[V_1 - P\,(1 - e^{-a})] + e^{-ak}\,[V_1 - P\,(1 - e^{a})]\} \qquad \ldots\ldots(2)$$

from equation (1).

From equation (2) the current at any point in the unit may be obtained in terms of P and V_1 by substituting values from 0 to 1 for k.

The two angles which are of most interest are the phase angle at the earthed end of the resistor and the phase angle at the high voltage end. These are obtained from a consideration of the resulting equations when k is made equal to 0 and then equal to 1 in equation (2).

Let the corresponding values of i be i_0 and i_1. Then

$$i_0 = \frac{1}{R}\frac{a}{e^{a} - e^{-a}}\{V_1 - P\,(1 - e^{-a}) + V_1 - P\,(1 - e^{a})\}$$

$$\frac{a}{R\,(e^{a} - e^{-a})}\{2\,(V_1 - P) + P\,(e^{a} + e^{-a})\}$$

$$\frac{}{R\sinh a}\{V_1 - P + P\cosh a\}.$$

The expansion of sinh a and cosh a gives the relation

$$i_0 = \frac{a\left[V_1 - P + P\left(1 + \frac{a^2}{L^2} + \frac{a^4}{L^4}\cdots\right)\right]}{R\left(a + \frac{a^3}{L^3} + \frac{a^5}{L^5}\cdots\right)}$$

$$= \frac{\left(V_1 + \frac{Pa^2}{L^2} + \frac{Pa^4}{L^4}\right)}{R\left(1 + \frac{a^2}{L^3} + \frac{a^4}{L^5}\cdots\right)} \qquad \ldots\ldots(3).$$

Similarly

$$i_1 = \frac{V_1 + \frac{(V-P)\,a^2}{L^2} + \frac{(V-P)\,a^4}{L^4}}{R\left(1 + \frac{a^2}{L^3} + \frac{a^4}{L^5}\right)} \qquad \ldots\ldots(4).$$

The cases where the screen potential P is zero and when it has a value equal to that of the mid-point of the resistor are of special interest, *i.e.* when (a) $P = 0$ and (b) $P = V_1/2$.

(a) By putting $P = 0$ in equation (3) we get

$$i_0 = \frac{V_1}{R\left(1 + \frac{a^2}{6} + \frac{a^4}{120}\right.}$$

$$= \frac{V_1}{R}\left(1 - \frac{a^2}{6}\cdots\right), \text{ neglecting terms in } a^4 \text{ etc.}$$

$$\frac{V_1}{R}\left(1 - \frac{jRC\omega}{6}\right).$$

The term in a^4 is a "real" term, and only affects the phase angle by introducing a term in a^6—a third order term which in general is negligible. Thus the phase angle at the earthed end is $- RC\omega/6$. The case considered above, when $P = 0$, is the case of a resistor which is unshielded and has uniformly distributed capacity C to earth.

By putting $P = 0$ in equation (4) we get

$$i_1 = \frac{\frac{V_1}{R}\left(1 + \frac{a^2}{L^2}\cdots\right)}{1 + \frac{a^2}{L^3}\cdots},$$

$$= \frac{V_1}{R}\left(1 + \frac{a^2}{3}\right), \text{ neglecting higher powers of } a^2$$

$$= \frac{V_1}{R}\left(1 + \frac{jRC\omega}{3}\right).$$

The phase angle at the high voltage end of the unit shielded by earth potential is $+ RC\omega/3$.

(b) By putting $P = V_1/2$ in equations (3) and (4) and letting α stand for the phase angle at the earthed end, and β for the phase angle at the high voltage end of the unit we find that

$$\alpha = \frac{RC\omega}{12},$$

$$\beta = \frac{RC\omega}{12}.$$

It will be seen that the phase angle is the same at the high voltage end as at the low voltage end. This case, where the currents at each end of a unit are in phase, is a very important one in practice. When a resistor is used consisting of several shielded units in series, the screens are generally maintained at the mean potential of the units they are shielding.

It is useful to have an expression giving the values of the phase angles α and β for small variations of the screen potential from the mean potential $V_1/2$.

Let $P = \frac{V_1}{2} + \frac{V_1 n}{200} = V_1 \frac{(100 + n)}{200}$, where n represents the percentage variation of the voltage on the shield from $V_1/2$.

Then $$\alpha = + \frac{RC\omega\,(100 + 3n)}{1200}$$

and $$\beta = + \frac{RC\omega\,(100 - 3n)}{1200} \qquad \ldots\ldots(6).$$

So far the screen potential has been considered as being in phase with the voltage across the unit which it is shielding. In a resistor consisting of a number of shielded units, where the shield potentials are maintained by means of an auxiliary resistance connected across the supply, small phase displacements may occur between the voltage across a unit and the voltage on the screen. The possible effect of this phase displacement on the angles α and β merit some attention. Taking the case where the nominal shield potential is $V_1/2$, let $P = V_1(1 + jS)/2$, where $\tan^{-1} S$ is a small angular displacement between P and V_1. Then

$$i_0 = \frac{V_1}{R} \frac{\left[1 + \frac{1}{2}(1 + jS)\frac{a^2}{2} \ldots\right]}{\left[1 + \frac{a^2}{6} \ldots\right]},$$

$$= \frac{V_1}{R}\left[1 + \frac{a^2}{12} + \frac{jSa^2}{4}\right], \text{ neglecting terms in } a^4 \text{ etc.}$$

$$= \frac{V_1}{R}\left[1 + \frac{jRC\omega}{12} + \frac{j^2 RC\omega S}{4}\right],$$

$$= \frac{V_1}{R}\left(1 - \frac{RC\omega S}{4}\right)\left[1 + \frac{jRC\omega}{12\left(1 - \frac{RSC\omega}{4}\right)}\right].$$

The term $RCS\omega/4$ contains the product of the small quantities C and S and consequently can in general be neglected compared with 1, so that $\alpha = + RC\omega/12$, *i.e.* is not appreciably changed by a small phase displacement between the shield voltage and the unit voltage.

Similarly it can be shown that

$$i_1 = \frac{V_1}{R}\left(1 - \frac{RCS\omega}{4}\right)\left[1 + \frac{jRC\omega}{12\left(1 - \frac{RCS\omega}{4}\right)}\right],$$

and therefore $$\beta = + \frac{RC\omega}{12}.$$

Numerical Examples.

Consider a unit where $R = 20{,}000$ ohms, $C = 100$ micromicrofarads and $\omega = 2\pi \times 50$,

$$RC\omega = \frac{20{,}000 \times 100 \times 314}{10^{12}} = 0{\cdot}0006;$$

when $P = 0$, $\alpha = -\frac{RC\omega}{6} = -0{\cdot}0001$,

$\beta = +\frac{RC\omega}{3} = +0{\cdot}0002$;

when $P = V_1/2$, $\alpha = \beta = +\frac{RC\omega}{12} = +0{\cdot}00005$;

when $P = V_1(1 + 0{\cdot}1j)/2$, *i.e.* when P is displaced from V_1 by an angle of about six degrees, the correction factor $\frac{RC\omega S}{4} = 0{\cdot}00001_5$ which can be neglected compared with unity.

(3) Shielded Units Connected in Series

Having considered the characteristics of a single unit shielded at a known potential, it remains to consider the phase angle at a point in a resistor which is made up of a number of units exactly alike and shielded similarly. That is to say, if $V_1 - V_0$, $V_2 - V_1$, ... $V_m - V_{m-1}$ represent the voltages across the units 1, 2 ... m, and $P_1 P_2 \ldots P_m$ represent the voltages applied to the shields.

Then $V_m - V_{m-1}$ and $\frac{P_m}{V_m - V_{m-1}}$ are constants.

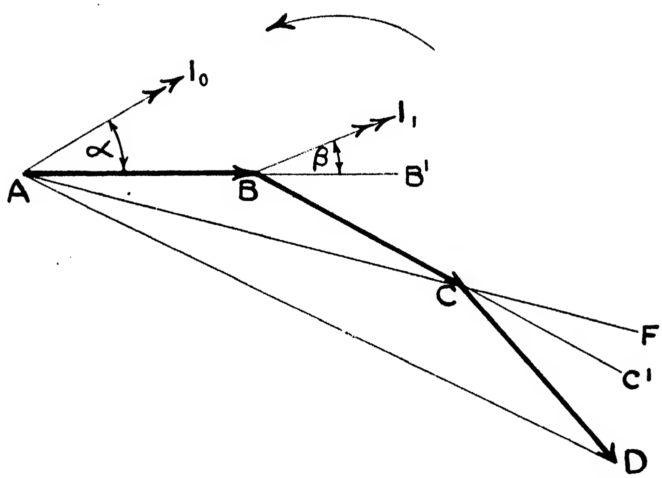


Fig. 2

In Fig. 2 let AB represent the voltage vector $V_1 - V_0$, and let AI_0 and BI_1 indicate the direction of the currents, at the low and high voltage ends of the unit respectively.

Then angle $I_0AB = \alpha$, the phase angle at the low voltage end of the unit, and angle $I_1BB' = \beta$, the phase angle at the high voltage end of the unit, B' lying on AB produced.

The current i_1 at the high voltage end of the first unit is the same as that at the low voltage end of the second unit, and the current at the low voltage end of the second unit bears the same phase relation to the voltage across it, as the current at the low voltage end of the first unit does to the voltage across it.

Hence if BC represent the voltage vector $V_2 - V_1$ then angle $I_1BC = \alpha$. The angle between AB and BC equals $\alpha - \beta$. That is to say the angle between the vector representing the voltage across the first unit and the vector representing the voltage across the second unit is $\alpha - \beta$. Similarly it may be shown that the angle between the voltages across successive units is $\alpha - \beta$.

In a resistor for high voltages the two-phase angles which are of importance are the phase angle at the low voltage end of the resistor, or the angle between the current at the low voltage end and the voltage across the resistor, and the phase angle at the high voltage end.

Let ϕ_1 and ϕ_2 represent the phase angles at the low and high voltage ends respectively of the resistor. Then for a resistor consisting of one unit

$$\phi_1 = \angle I_0AB = \alpha.$$

For a resistor of two units the phase angle is represented by the angle I_0AC, and for three units by the angle I_0AD and so on.

A general expression for ϕ_1 when the number of units is m may be derived as follows:

For a resistor of 1 unit, $\phi_1 = \angle I_0AB = \alpha$.

For a resistor of 2 units, $\phi_1 = \angle I_0AC = \alpha + \angle BAC$.

For a resistor of 3 units, $\phi_1 = \angle I_0AD = \alpha + \angle BAC + \angle CAD$.

$$\angle B'BC = \alpha - \beta,$$

and since $AB = BC$, $\angle BAC = \frac{1}{2}(\alpha - \beta)$.

Let BC be produced to C' and AC to F,

$$\begin{aligned}\angle FCD &= \angle FCC' + \angle C'CD,\\ &= \frac{\alpha - \beta}{2} + \alpha - \beta = \frac{3(\alpha - \beta)}{2},\\ &= \angle CAD + \angle CDA.\end{aligned}$$

$$\frac{\text{Sine} \angle CAD}{\text{Sine} \angle CDA} = \frac{CD}{CA}.$$

Since all the angles involved are small,

$$\frac{\angle CAD}{\angle CDA} = \frac{CD}{2CD},$$

$$\therefore \quad \frac{\angle CAD}{\angle CAD + \angle CDA} = \frac{CD}{3CD},$$

i.e.
$$\begin{aligned}\angle CAD &= \tfrac{1}{3}[\angle CAD + \angle CDA],\\ &= \tfrac{1}{3} \times \tfrac{3}{2}(\alpha - \beta) = \frac{\alpha - \beta}{2}.\end{aligned}$$

Similarly it can be shown that for each unit added ϕ_1 is increased by $\frac{1}{2}(\alpha - \beta)$.

For a resistor consisting of m units

$$\phi_1 = \alpha + (m - 1)\tfrac{1}{2}(\alpha - \beta) \qquad \ldots\ldots(7).$$

Similarly it can be shown that

$$\phi_2 = \beta - (m - 1)\tfrac{1}{2}(\alpha - \beta) \qquad \ldots\ldots(8).$$

From equations (5), (6) and (7) we obtain the relation

$$\phi_1 = \frac{RC\omega}{1200}[100 + 3nm] \qquad \ldots\ldots(9).$$

From equations (5), (6) and (8) we obtain the relation

$$\phi_2 = \frac{RC\omega}{1200}[100 - 3mn] \qquad \ldots\ldots(10).$$

Relations (9) and (10) give the phase angle of a shielded resistor, at the low voltage and high voltage ends respectively, in terms of the characteristics R and C of one unit, the number of units m and n, where n is the percentage deviation of the shield voltages from the mean value of the voltage in the appropriate unit.

By making $n = -100/3m$ in equation (9), we obtain the condition for ϕ_1 to be zero. This value, however, is not used in practice since it makes the shield potential dependent on the number of units, and consequently would be a source of inconvenience when the size and range of the resistor were being modified. When n has this value ϕ_2 equals $RC\omega/6$.

By making n zero $\phi_1 = \phi_2 = RC\omega/12$, and the phase angle at the high voltage end of the resistor is the same as the phase angle at the low voltage end. This is probably the most suitable value for n since the constants R and C for a unit may be so arranged as to give a negligibly small value to $RC\omega/12$.

Equations (9) and (10) show that ϕ_1 and ϕ_2 are directly proportional to n, and to m. Thus when a large number of units is used, the necessity for keeping n small is shown.

Example.

Let	$m = 100$,
when $n = 0$,	$\phi_1 = RC\omega/12$,
when $n = 1$,	$\phi_1 = RC\omega/4$.

When a resistor of 100 units is used a maladjustment of the shields of 1 per cent. increases ϕ_1 to three times its normal value.

IMPROVED ARRANGEMENT FOR INTEGRATING PHOTOMETER.

By B. P. DUDDING and G. T. WINCH. (Communication from the Staff of the Research Laboratories of the General Electric Company, Ltd., Wembley.)

[*MS. received, 20th June*, 1928.]

ABSTRACT. The paper gives details of a new simplified type of photometer head incorporating Lummer Brodhun contrast prisms and a sector disc. The use of this head with an integrating photometer is described. When so used, a small portion of the internal surface of the integrator forms one half of the field of view and a comparison disc having an identical surface forms the other half, both surfaces being viewed at the same angle. The advantages of the arrangement are stated.

General Principles

This photometer incorporates Lummer Brodhun prisms of the contrast type so arranged that a small portion of the wall of the integrator is viewed at an angle of 45° through a hole about 15 mm. diameter. The comparison lamp illuminates a white disc which is made of the same material and painted with the same paint as the interior of the integrator. This whitened screen is also viewed at 45° through the Lummer Brodhun prisms and forms the comparison side of the photometer field.

(1) *Advantages of the New Method*

The main advantages of the arrangement are:

1. A closer approximation to the theoretical desideratum of measuring the integrator wall brightness.

2. The large range of candle-power which can be measured by using suitably calibrated sector discs (from about 0·5 to 300 candles in a 1-metre sphere).

There is also an associated advantage in that, having calibrated the sector discs using standard lamps of the more usual size, the apparatus can be used to measure either much larger or much smaller lamps.

3. The reduction of selective colour difference to a minimum.

There are no diffusing windows, and as the surface of the comparison field is formed of the same material as the integrator and is painted at the same time with the same paint, it is clear that the only selectivity introduced is that due to the multiple reflections in the integrator. We have found that this directly affects and improves the precision of individual observations.

4. The ease with which the apparatus can be fitted to any integrator and used with an existing horizontal photometer bench without involving any alteration to the bench.

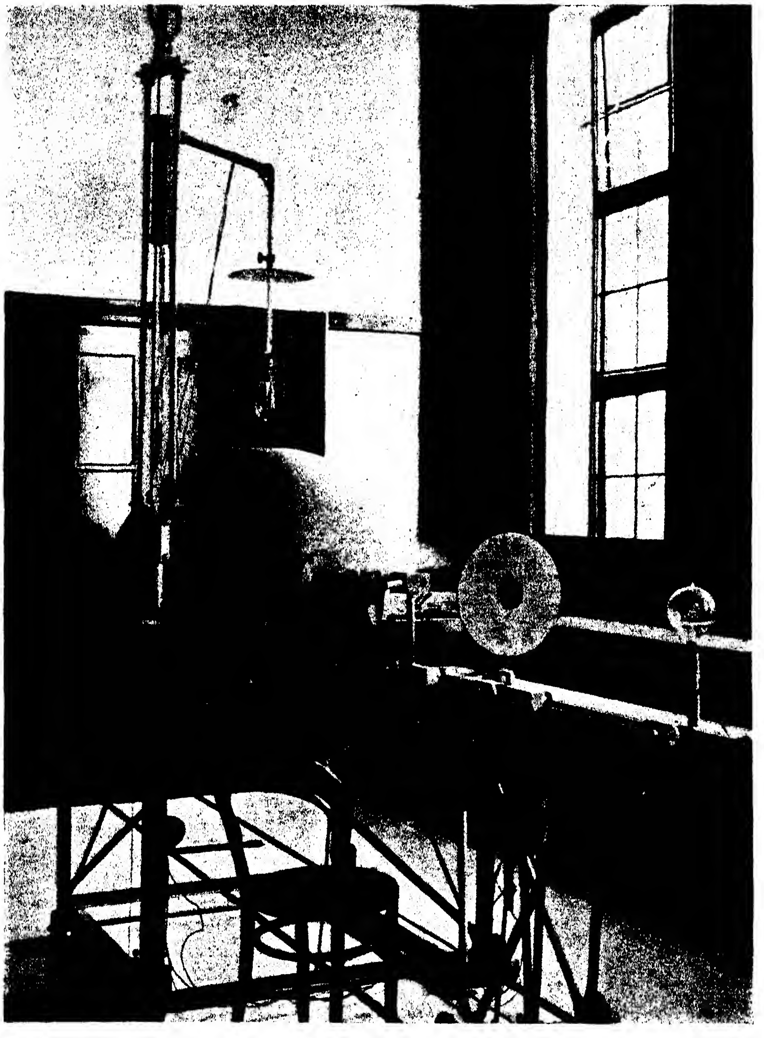


Fig. 1. The new type of head fitted to a sphere and horizontal photometer bench

(2) *Construction*

The photometer is constructed as a unit that can be conveniently fitted to a normal horizontal or vertical photometer bench which in turn may be linked to an integrating unit.

Fig. 1 is a photograph of the new type of head fitted to a sphere and horizontal photometer bench.

Fig. 2 shows the photometer head dismantled.

Fig. 3 shows a line diagram of the photometer head.

(3) *Description of Apparatus*

The apparatus is used with suitable sectors to cover the range of candles required. The ratio of these discs can be determined accurately, after which they can be used to adjust the field brightness according to the type of lamps being measured.

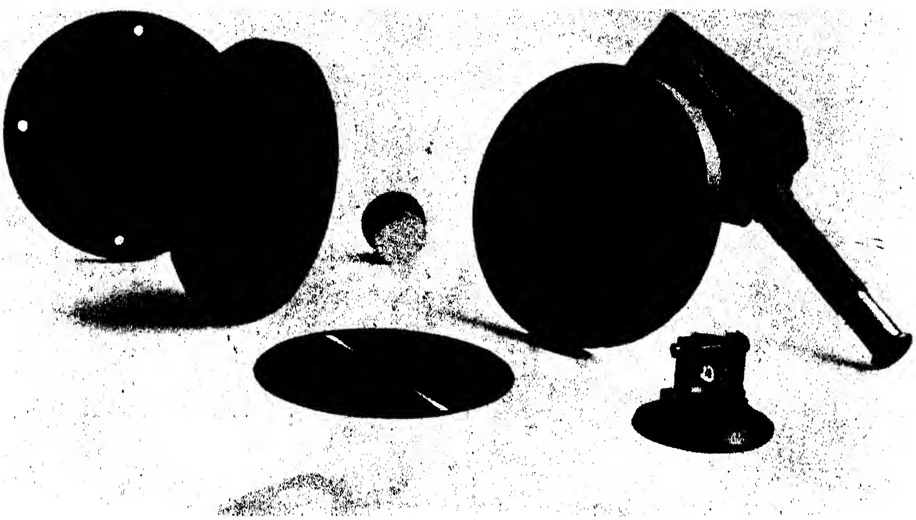


Fig. 2. The photometer head dismantled

The following figures may be of interest as an example to show how conveniently the field brightness and the candle-power ranges can be adjusted by using suitable sector discs.

Type of lamp	Approximate illumination on wall of integrator in metre candles	Candles of lamp	Suitable sector disc	Approximate illumination on the photometer screen in metre candles
Miner's bulb	16	1	No sector	16·0
Motor-car headlight	320	20	1/20	16·0
H.V. 60W. gas filled	736	46		7·4
H.V. 100W. ,,	1440	90	1/100	14·4
H.V. 300W. ,,	5440	340		54·4

The sector disc is driven by a small pressure air turbine. Any small motor is suitable provided that motor vibration is not transmitted to the photometer head. This type of motor was chosen mainly for cheapness and lightness, as an electric motor of the same power would need much more substantial support in order to prevent objectionable vibration being transmitted to the rest of the apparatus.

The Lummer Brodhun prisms used were of the contrast type, having a 9 mm. field, and were so arranged that the eye views the inside wall of the integrator through a small hole. This forms one half of the field of view, while the other half is formed from the whitened disc which is illuminated by the comparison lamp. The size of the viewed portion of the wall of a 1-metre integrator is about 10 sq. cm. in area, so that it can be conveniently screened from direct light.

The prisms are mounted on a separate locating disc which is quickly detachable for inspection and cleaning purposes. It also allows the prisms to be rotated while the field is being viewed, so that the correct position can quickly be obtained and the prisms clamped before proceeding with observations. The white comparison surface is carried on a plug which can be unscrewed to facilitate repainting, which is desirable every time the integrator is painted. The photometer head is attached to the sphere by means of a flexible connexion, which serves to prevent the entrance of stray light into the photometer head.

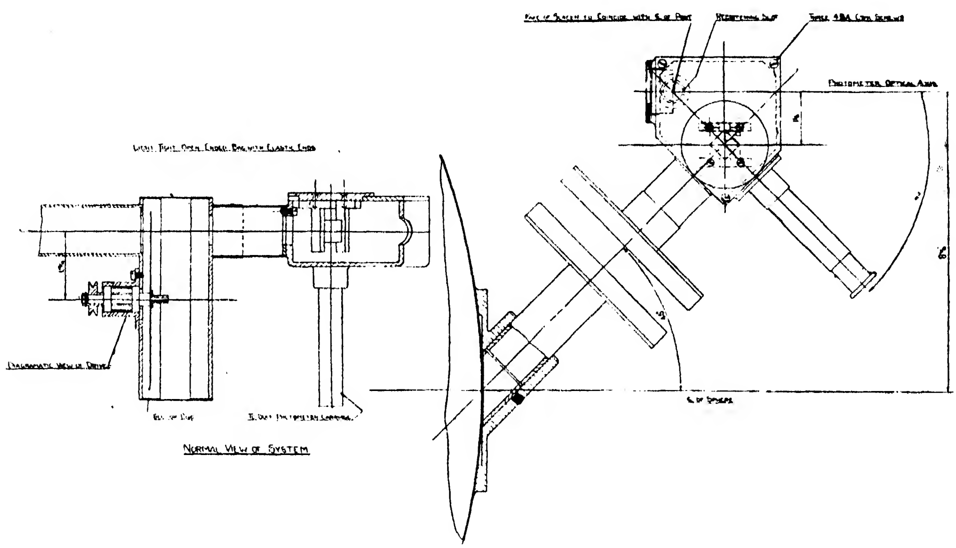


Fig. 3. Line diagram of the photometer head

This principle has been employed in the modification of a 2 ft. side cubical integrating photometer used for measuring life test lamps, etc., which had previously employed a diffusing window. In this case a slight modification was necessary in order to adapt the new principle more conveniently to the existing apparatus, which employs a comparison lamp travelling vertically.

AN EXPANSION METHOD OF MEASURING THE PELTIER COEFFICIENT. By PROF. G. W. TODD, M.A., D.Sc., F.Inst.P.

Armstrong College, Newcastle-on-Tyne.

[*MS. received, 27th June*, 1928.]

ABSTRACT. When a current is passed through the wires of a thermoelectric junction the alteration in temperature at the junction produces a change in length over and above that produced by the resistance heating effect. An expression for this change in length is developed in terms of the Peltier coefficient and other properties of the metals forming the couple. The experimental arrangement is such as to eliminate the resistance heating effect.

The experimental demonstration of the Peltier effect is a comparatively easy matter especially with a pair of metals distantly separated on the thermoelectric scale, but the quantitative measurement of the coefficient offers considerable difficulty on account of the minuteness of the heat-production or absorption compared with the resistance heating effects. The

method described in this paper consists in measuring the expansions produced in the wires of a thermojunction by direct and reversed currents, the wires being arranged in such a way as to eliminate the resistance heating effects by compensation. The method is a rapid one and admits of considerable accuracy.

Let X_1OX_2 (Fig. 1) represent a thermojunction of metals 1 and 2 with the junction at O. If metal 1 has a greater resistance per unit length than metal 2, and has a similar emissivity, then the steady temperature conditions on passing a current along the wires will be represented by the graph, θ_1 being greater than θ_2. Consider an element dx of one of the metals (say 2) at a distance x from the junction O. Equating the rates of accumulation and emission of heat gives

$$Ak\frac{d^2\theta}{dx^2}\,.\,dx + 0{\cdot}24\,i^2R\,.\,dx = \epsilon p\theta\,.\,dx$$

where A = cross-section, k = thermal conductivity, i = current, R = resistance per unit length, ϵ = emissivity, p = perimeter, and θ = excess temperature.

Or,
$$\frac{d^2\theta}{dx^2} - \kappa^2\theta + n = 0,$$

if we put $\kappa^2 = \epsilon p/Ak$ and $n = 0{\cdot}24\,i^2R/Ak$.

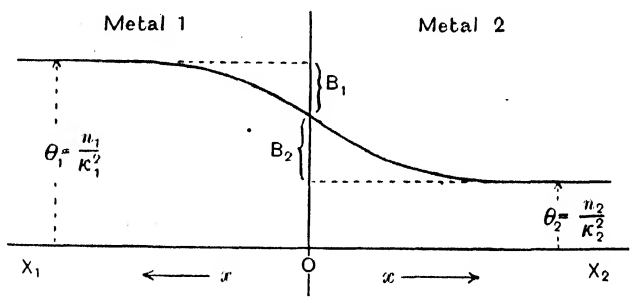


fig. 1.

Thus the excess temperature of metal 2 at distance x from the junction is given by

$$\theta_2 = B_2\,e^{-\kappa_2 x} + \frac{n_2}{\kappa_2^2} \qquad \text{......(1).}$$

B_2 being a constant.

When $x = \infty$, $\theta_2 = \frac{n_2}{\kappa_2^2}$ and when $x = 0$, $\theta_2 = B_2 + \frac{n_2}{\kappa_2^2}$.

The excess temperature of metal 1 at distance x from the junction is given by

$$\theta_1 = \frac{n_1}{\kappa_1^2} - B_1\,e^{-\kappa_1 x} \qquad \text{......(2),}$$

B_1 being a constant.

When $x = \infty$, $\theta_1 = \frac{n_1}{\kappa_1^2}$ and when $x = 0$, $\theta_1 = \frac{n_1}{\kappa_1^2} - B_1$.

The values of the constants B_1 and B_2 are seen in Fig. 1. It is also obvious that the temperature of the junction is

$$\theta_0 = \frac{n_1}{\kappa_1^2} - B_1 = B_2 + \frac{n_2}{\kappa_2^2}$$

and
$$B_1 + B_2 = \frac{n_1}{\kappa_1^2} - \frac{n_2}{\kappa_2^2} = 0{\cdot}24\,i^2\left(\frac{R_1}{\epsilon_1 p_1} - \frac{R_2}{\epsilon_2 p_2}\right).$$

The extension of dx at x is $\alpha \,.\, \theta \,.\, dx$, where $\alpha =$ coeff. of expansion. Therefore if l_1 and l_2 are the lengths of the two metal wires, the total expansion will be

$$E_{\pm i} = \int_0^{l_1} \alpha_1 \theta_1 \,.\, dx + \int_0^{l_2} \alpha_2 \theta_2 \,.\, dx$$

$$= \frac{\alpha_1 n_1 l_1}{\kappa_1^2} + \frac{\alpha_1 B_1}{\kappa_1}(e^{-\kappa_1 l_1} - 1) + \frac{\alpha_2 n_2 l_2}{\kappa_2^2} - \frac{\alpha_2 B_2}{\kappa_2}(e^{-\kappa_2 l_2} - 1) \qquad \ldots\ldots(3),$$

on substituting equations (1) and (2).

If there is no Peltier effect, B_1 and B_2 will have the same values independent of the direction of the current. If a Peltier effect exists, B_1 and B_2 will become B_1' and B_2', but the sum

$$B_1' + B_2' = B_1 + B_2 = \frac{n_1}{\kappa_1^2} - \frac{n_2}{\kappa_2^2}$$

as before.

When the current is reversed the constants become B_1'' and B_2'' and we still have

$$B_1'' + B_2'' = B_1 + B_2 \quad \text{(see Fig. 2)}.$$

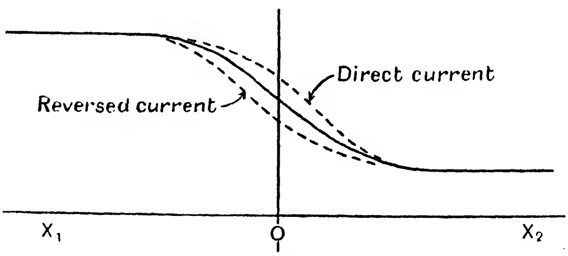


fig. 2.

Thus equation (3) determines the expansion ($E_{\pm i}$) without the Peltier effect (constants B_1 and B_2), the expansion (E_{+i}) with the Peltier effect (constants B_1' and B_2'), and the expansion (E_{-i}) with the Peltier effect (constants B_1'' and B_2''). The expansion due to the Peltier effect alone is $E_{\pm i} \sim E_{+i}$ or $E_{\pm i} \sim E_{-i}$ according to the direction of the current.

$$E_{\pm i} \sim E_{+i} = \frac{\alpha_1}{\kappa_1}(e^{-\kappa_1 l_1} - 1)(B_1' - B_1) - \frac{\alpha_2}{\kappa_2}(e^{-\kappa_2 l_2} - 1)(B_2' - B_2)$$

$$= (B_1 - B_1')\left(\frac{\alpha_1}{\kappa_1} - \frac{\alpha_2}{\kappa_2}\right) \qquad \ldots\ldots(4),$$

if l_1 and l_2 are great, or, which amounts to the same thing, assuming that the results of the Peltier effect are confined to the region close to the junction.

Now the heat developed at the junction is Πi per second where Π is the Peltier coefficient. Since the temperatures of the wires at $x = \infty$ are the same whether there is a Peltier effect or not, there must be an increased emission from the wires in the region $x = 0$ in order to maintain steady conditions. The additional emission must be given by

$$\Pi i = \int_0^\infty \epsilon_2 p_2 (\theta_{B_2'} - \theta_{B_2})\, dx + \int_0^\infty \epsilon_1 p_1 (\theta_{B_1'} - \theta_{B_1})\, dx$$

$$= \epsilon_2 p_2 \int_0^\infty \left\{\left(B_2' e^{-\kappa_2 x} + \frac{n_2}{\kappa_2^2}\right) - \left(B_2 e^{-\kappa_2 x} + \frac{n_2}{\kappa_2^2}\right)\right\} dx$$

$$+ \epsilon_1 p_1 \int_0^\infty \left\{\left(\frac{n_1}{\kappa_1^2} - B_1' e^{-\kappa_1 x}\right) - \left(\frac{n_1}{\kappa_1^2} - B_1 e^{-\kappa_1 x}\right)\right\} dx$$

$$= (B_1 - B_1')\left(\frac{\epsilon_1 p_1}{\kappa_1} - \frac{\epsilon_2 p_2}{\kappa_2}\right) \qquad \ldots\ldots(5).$$

And a similar expression, with the B''s replaced by B'''s, holds for $\Pi' i$ when the current is reversed.

By dividing (5) by (4) the constants are eliminated and we obtain

$$\frac{\Pi i}{E} = \left(\frac{\epsilon_1 p_1}{\kappa_1} - \frac{\epsilon_2 p_2}{\kappa_2}\right) \Big/ \left(\frac{\alpha_1}{\kappa_1} - \frac{\alpha_2}{\kappa_2}\right) \qquad \text{......(6),}$$

which is the expression we use for the calculation of the Peltier coefficient.

The experimental arrangement is indicated in Fig. 3 where MPN is, say, nickel wire and NC, MC are copper wires, the junctions being at M, N. The ends C, C are bent over into mercury cups which are connected to a reversing key κ and the current is varied and measured by means of the rheostat R and ammeter A respectively. The nickel wire at P is firmly clamped between insulating blocks and this clamping is sufficient to support the rest of the wire and the doubly suspended concave mirror m the vibrations of which are damped by the vanes and dashpot d. In addition the suspended system is protected from draughts by a surrounding screen. The movement of the mirror is observed by means of a lamp and scale.

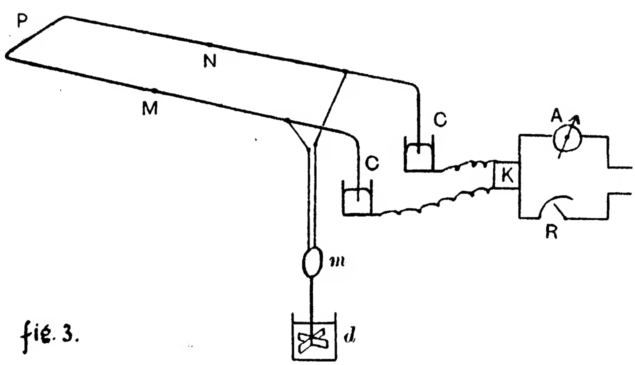


Fig. 3.

When a current passes round the wires there is an expansion in both arms owing to the resistance heating effect and this expansion is independent of the current direction. With the current in one direction there is, in addition, absorption of heat at N and production at M. When the current is reversed, these Peltier effects are also reversed. If we assume that the Peltier coefficients are exactly the same at M and N (*i.e.* we neglect the minute difference necessitated by the Thomson effect), then the excursion of the spot of light on reversing the current represents $4E$ in equation (6). Any possible heating effects at the mercury cups, which may be slightly different on current reversal, do not affect the movement of the mirror, the distance from the mercury to the bend in the wire being such that the heat escapes by surface emission before reaching the bend.

The emissivity ϵ for the wires can be measured by separate experiments on each wire. The wire is fixed at one end and the expansion measured at a distance l from that end by means of the doubly suspended mirror, one point of suspension being attached to the wire and the other to a fixed point. For temperature equilibrium we have

$$0{\cdot}24 i^2 R = \epsilon p \theta.$$

The expansion produced by the heating of the current is

$$\Delta l = \alpha \theta l.$$

So that

$$\epsilon = 0{\cdot}24 \frac{\alpha l i^2 R}{p \,.\, \Delta l}.$$

The following particulars of an actual experiment with copper and nickel wires give an idea of the magnitudes of the measurements involved.

Emissivity measurements

	Copper (cm.)	Nickel (cm.)
Length of wire	17·3	16·6
Diameter of wire	0·160	0·124
Scale distance	168	168
Distance between points of suspension of mirror threads	0·190	0·215

Cu		Ni	
i (amps)	D (deflection)	i (amps)	D (deflection)
7·1	0·95 cm.	4·5	2·00 cm.
8·0	1·25 ,,	7·1	4·95 ,,
9·0	1·45 ,,	8·0	6·30 ,,
3·0	0·15 ,,	3·0	0·90 ,,
4·1	0·30 ,,	2·0	0·40 ,,
5·2	0·45 ,,	2·5	0·60 ,,

In both cases i^2 plotted against D gives a straight line over the range of currents used.

$$\frac{i^2}{D} = 52{\cdot}6 \qquad\qquad \frac{i^2}{D} = 10{\cdot}0,$$

$$\Delta l = 0{\cdot}190 \, \frac{D}{2 \times 168} = 5{\cdot}65 \times 10^{-4} D, \qquad \Delta l = 0{\cdot}215 \, \frac{D}{2 \times 168} = 6{\cdot}40 \times 10^{-4} D,$$

$$R = 8{\cdot}3 \times 10^{-5} \text{ ohms}, \qquad R = 9{\cdot}8 \times 10^{-5} \text{ ohms},$$

$$\alpha = 1{\cdot}67 \times 10^{-5}. \qquad \alpha = 1{\cdot}28 \times 10^{-5}.$$

$$\epsilon = 1{\cdot}06 \times 10^{-3}. \qquad \epsilon = 1{\cdot}31 \times 10^{-3}.$$

Peltier effect measurements

Lengths $PM = PN = 7$ cm. (Nickel.)

,, $NC = MC = 7$ cm. (Copper.) See Fig. 3.

We have the following data:

	Diameter (cm.)	p (cm.)	A (sq. cm.)	k (cals.)	a
Cu	0·160	0·503	0·0201	0·915	$1{\cdot}67 \times 10^{-5}$
Ni	0·124	0·389	0·0121	0·142	$1{\cdot}28 \times 10^{-5}$

Whence we obtain (see equation (6)):

	ϵp		$\epsilon p/\kappa$	a/κ
Cu	$5{\cdot}33 \times 10^{-}$	1·84	$3{\cdot}92 \times 10^{-}$	$1{\cdot}23 \times 10^{-5}$
Ni	$5{\cdot}10 \times 10^{-4}$	0·298	$9{\cdot}34 \times 10^{-}$	$2{\cdot}34 \times 10^{-5}$

Distance of scale from mirror = 168 cm.

Distance between points of suspension of mirror threads (unspun silk) measured with reading microscope = 0·160 cm.

The observed movement ϕ of the spot on the scale for reversal of the current is plotted against the current in Fig. 4. Over the range of currents employed the graph is linear, giving $\phi/i = 0{\cdot}236$ cm. per amp. Thus we have

$$\frac{4E}{0{\cdot}160} = \frac{\phi}{2 \times 168}.$$

$$\therefore \quad \frac{E}{i} = \frac{0{\cdot}160}{8 \times 168} \frac{\phi}{i} = 2{\cdot}81 \times 10^{-5}.$$

Substituting in (6) gives for the Peltier coefficient

$$\Pi = 2{\cdot}81 \times 10^{-5} \times \frac{9{\cdot}34 - 3{\cdot}92}{2{\cdot}34 - 1{\cdot}23} \times 10 \text{ calories per ampere second.}$$

$$= 4{\cdot}83 \text{ calories per ampere hour.}$$

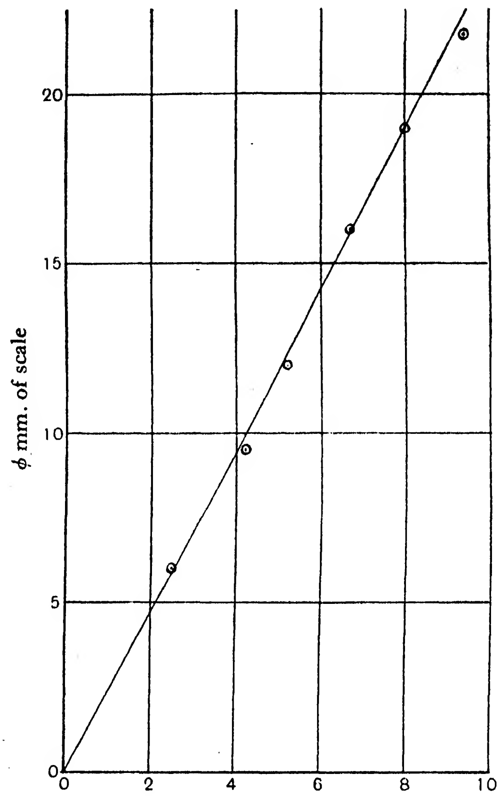


Fig. 4

The thermoelectric power of a Cu–Ni junction is approximately 20 microvolts per degree at ordinary temperatures. Taking the Peltier coefficient as the product of the absolute temperature into the thermoelectric power, we have at 300° absolute,

$$\Pi = 6000 \text{ microvolts}$$

$$= 5 \text{ calories per ampere hour approx.,}$$

which is in fair agreement with our experimental result.

NEW INSTRUMENTS

A PORTABLE ELECTRIC HARMONIC ANALYSER

THE most satisfactory method of studying the behaviour of alternating voltage or current waves which are distorted from a pure sine wave, is to consider the causes and effects of the various harmonics present. In the case of voltage waves of present-day alternators, this requires the measurement of harmonics which are usually not more than a few per cent. of the fundamental. Although the wave-form of an alternating voltage or current is usually

depicted by an oscillogram, it is generally recognized that the subsequent analysis of this trace in order to obtain the magnitudes of its harmonics does not lend itself to great accuracy, and is, moreover, exceedingly tedious.

The Electric Harmonic Analyser, as manufactured by H. Tinsley and Co., of South Norwood, London, S.E. 25, overcomes this difficulty and provides a means of making a direct measurement of the harmonics in either a voltage or current wave. With this apparatus each harmonic is found separately in a few minutes from steady readings on two instruments, and in the case of a voltage wave at about 100 volts small harmonics can be measured correct to at least 1/20th of 1 per cent. of the fundamental. In addition to measuring harmonics in voltages and currents, the apparatus can be used for determining the phase angle between harmonics of the same frequency in two different waves. Provision is not normally made for the measurement of the absolute phase angles of the various harmonics considered

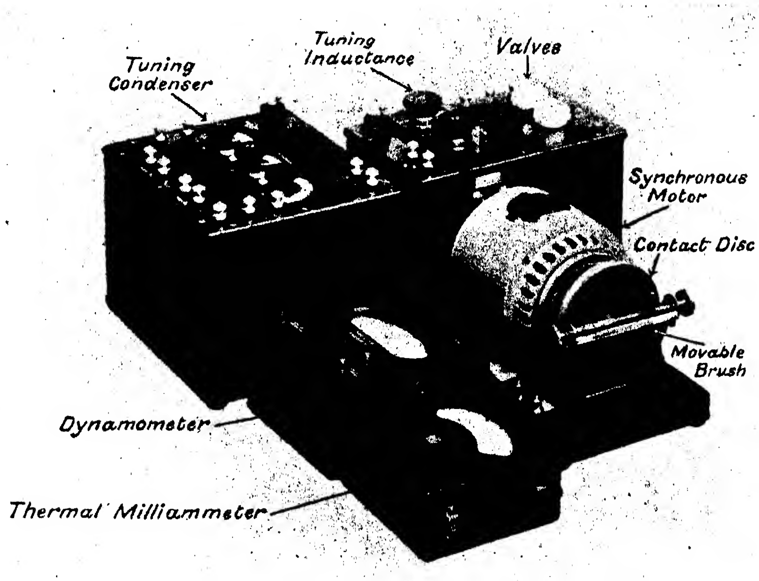


Fig. 1. Portable electric harmonic analyser

at the instant the fundamental passes through its zero value, as in most cases it is not important to know them. Where required, however, these absolute phases of the harmonics can be determined without undue difficulty. Fig. 1 shows the complete apparatus, which is arranged in a number of units for convenience in carrying about.

The Electric Harmonic Analyser is manufactured under the patent of Miles Walker and makes use of the dynamometer method of analysis described by R. T. Coe, in an article in *La Revue Générale de l'Électricité* of 6th Feb. 1926, entitled "Analyseur D'Ondes Électriques." This method is an improvement of an earlier method described in a paper* read before the Institution of Electrical Engineers in 1924. The principle involved is the elementary principle of the dynamometer that a steady deflection can only be produced by currents of the same frequency in the fixed and moving coils. Thus, a current related in some known way to the voltage or current to be analysed is passed through the moving coil of such an instrument, while through the fixed coil is passed a sinusoidal "analysing

* "An Electric Harmonic Analyser" by J. D. Cockcroft, R. T. Coe, J. A. Tyacke and Miles Walker. *Journal I.E.E.* **63**, p. 69.

current" of exactly the frequency of the harmonic to be found. To analyse a voltage wave this voltage is applied to the dynamometer moving coil through a series condenser, as shown in the diagram of Fig. 2, while to analyse a current wave the moving coil is connected directly across a suitable shunt carrying the given current.

The analysing current is obtained by means of a synchronously driven contact disc and a valve circuit, as indicated in Fig. 2. The face of the contact disc consists of a series of concentric rings of alternately insulating and conducting segments, which give the frequencies of the various harmonics, one ring being used for each harmonic. A movable brush is set on the ring corresponding to the required harmonic and the impulses of voltage are applied to the grid of a valve. The analysing current is then obtained in the final oscillatory circuit which is tuned approximately to this frequency by means of the thermal ammeter which is used to measure the analysing current.

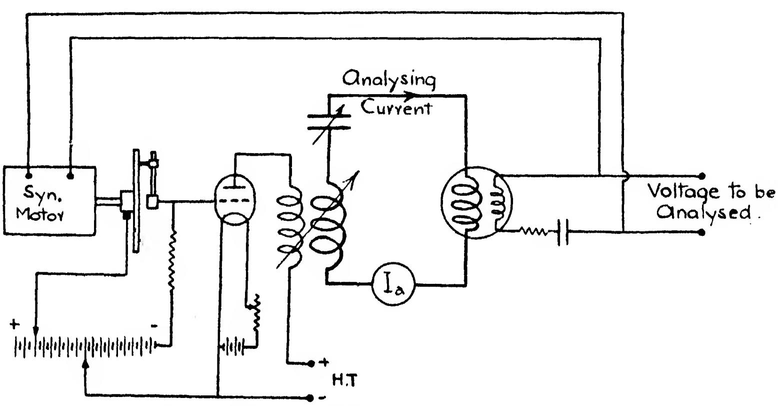


Fig. 2. Diagram of connexions

By rotating the arm which carries the movable brush, the phase of the analysing current is adjusted to give a maximum dynamometer deflection—D_{max}—which is given by the simple relation

$$D_{max} = kI_a I_n,$$

where I_n = required nth harmonic in moving coil current,

I_a = value of analysing current,

and k = d.c. calibration constant of dynamometer.

Thus $I_n = \dfrac{D_{max}}{kI_a}$ and can readily be calculated.

The harmonic in the applied voltage is given in volts by

$$V_n = I_n Z_n,$$

where Z_n = impedance of moving coil circuit at the frequency of the nth harmonic.

For the analysis of voltage waves at about 100 volts, when a condenser is used in series with the dynamometer moving coil, a calibration curve is supplied with the apparatus, giving the dynamometer deflection for a 1 volt harmonic in the applied wave and for a given value of analysing current, this curve having been calculated from the fundamental equations given above and the known constants of the moving coil circuit. The disc provided with the analyser gives all the odd harmonics from the 3rd to the 35th, this covering the range required for most investigations of electrical waves. Higher odd harmonics and even harmonics, if required, can be arranged for on a second disc, the discs being readily interchangeable.

A valuable application of the analyser is in the checking of the perfection of the voltage wave-form of an alternator specially designed to give a good sine wave. As an example of such use the accompanying oscillogram of Fig. 3 (reproduced by permission of the British Thomson-Houston Co., Ltd.) shows the open circuit voltage wave of a 350 kVA, 1200 volt, 50 cycle special sine wave alternator supplied to the N.P.L. by the British Thomson-Houston Co., Ltd., for use as the power supply for high voltage testing. The harmonics in this wave are so small that they cannot be detected in the oscillogram, and measurements made with the Electric Harmonic Analyser confirmed the fact that they were very small indeed. Analysis up to the 33rd harmonic showed that all the harmonics were less than 1/100th of 1 per cent. of the fundamental, except the field form harmonics, the 5th and 7th, which were only 0·1 per cent. and 0·03 per cent. respectively, and the tooth ripple harmonics, the 23rd and 25th, which were only 0·20 per cent. and 0·21 per cent. respectively.

Fig. 3. Open circuit voltage wave of a B.T.-H. special sine-wave alternator

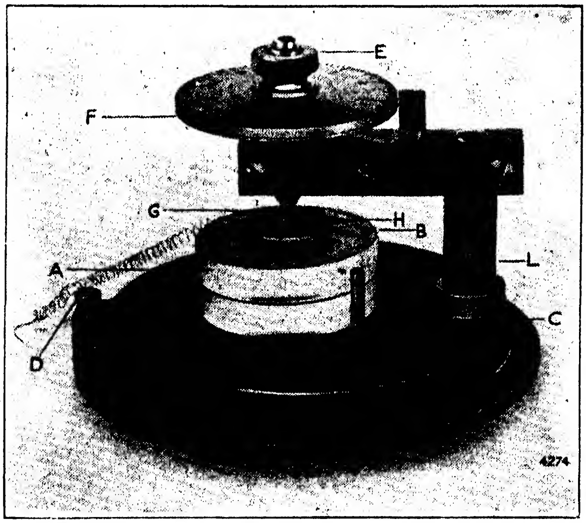
The apparatus should form a useful addition to any electrical laboratory, as apart from its main application of analysing waves, the separate items of the equipment, such as the synchronous motor, sine-wave generator, 3-dial condenser, thermal ammeter and astatic dynamometer have many other uses.

A MICROMETER FOR MEASURING THE THICKNESS OF VARNISH FILMS

In carrying out chemical and physical tests on samples of paint and varnish it is important that the thickness of the film or coating to be tested should be known to a high degree of accuracy. Slight deviations in this factor are likely to cause discrepancies in the final comparison data, which may deal with some characteristic such as the strength. Owing to the small measurements involved, more especially with varnish where the film is extremely fine, an apparently negligible inaccuracy often represents a high percentage error, and its effect, after conversion through several stages of an experiment, may vitiate the accuracy of conclusions based on such tests. The ordinary type of micrometer screw gauge is sometimes not suitable for measuring the thickness of the film, as the pressure of the micrometer screw may not be adjusted with sufficient accuracy by hand, or with the same pressure by two different operators. Moreover, since the screw indicates at only one point of the surface, unless the film is absolutely even a further error may be introduced.

The illustration shows apparatus which has been developed by the Cambridge Instrument

Company, Limited, 45 Grosvenor Place, London, S.W. 1, in conjunction with Mr Peters and Mr L. A. Walker of Messrs Docker Bros., of Birmingham, whereby a mean reading over the whole of the surface of a film or layer of dry varnish may be easily and accurately obtained. The dry film, the thickness of which it is desired to measure, is placed between the two glass plates (*A*). These plates are ground and polished quite flat and are of uniform thickness throughout, the plates usually supplied being 64 mm. in diameter and 12 mm. thick. A V-slot (*B*) into which a pin fits loosely, is cut into the side of each plate so that the plates will always return to the same spot when observations are made, the vertical rod (*C*), against which the plates are pressed, ensuring alignment of the edges. Levelling screws support the plates on the heavy metal base, but these are locked in position by nuts and adjustment is not necessary in ordinary use. The terminal (*D*) on the base is for the electrical circuit connexions to which subsequent reference is made. The brass column (*L*) rising from the base supports a rigid horizontal arm which carries a micrometer screw of 1 mm. pitch, adjustment being made by the knurled knob (*E*). Immediately below the knob is a horizontal dial (*F*) carrying a scale divided into 400 parts, registering against the



brass vertical reader fixed to the carrier arm. On the tip of the micrometer screw is mounted a silver contact, which, when observations are carried out, is adjusted to touch a gold contact similarly fixed to the brass disc (*H*). This disc, which also carries a terminal (*G*) for the electrical connexion, and has three toes soldered to its underside, is 30 mm. in diameter and stands on the top surface of the upper glass plate as shown.

When in use the operator wears a pair of 4000 ohm head-phones which are connected through a battery to the electrical terminals (*D* and *G*) on the base of the instrument and on the brass disc respectively. The body of the instrument being of metal a complete circuit is formed immediately the micrometer screw is adjusted into contact with the disc (*H*) and at the exact moment of contact a click is clearly audible in the head-phones, obviating the need for any special care in operation.

The method of obtaining varnish films is as follows: The varnish under examination is caused to flow down a sheet of tin amalgamated with mercury. The film is allowed to dry and then peeled off from the tin. To use the instrument the glass discs are first placed in position and a reading taken without the film to be measured. The film is then placed between the glass plates and a reading obtained by difference.

The special advantages of the instrument are the constant repeat conditions, and the mean reading for the whole of the surface between the glass plates.

THE AMSLER INTEGRATING WATER GAUGE

THE integrating water gauge (Alfred J. Amsler and Co., Schaffhouse, Switzerland) is used to measure and indicate continually on a counter the amount of water that passes through

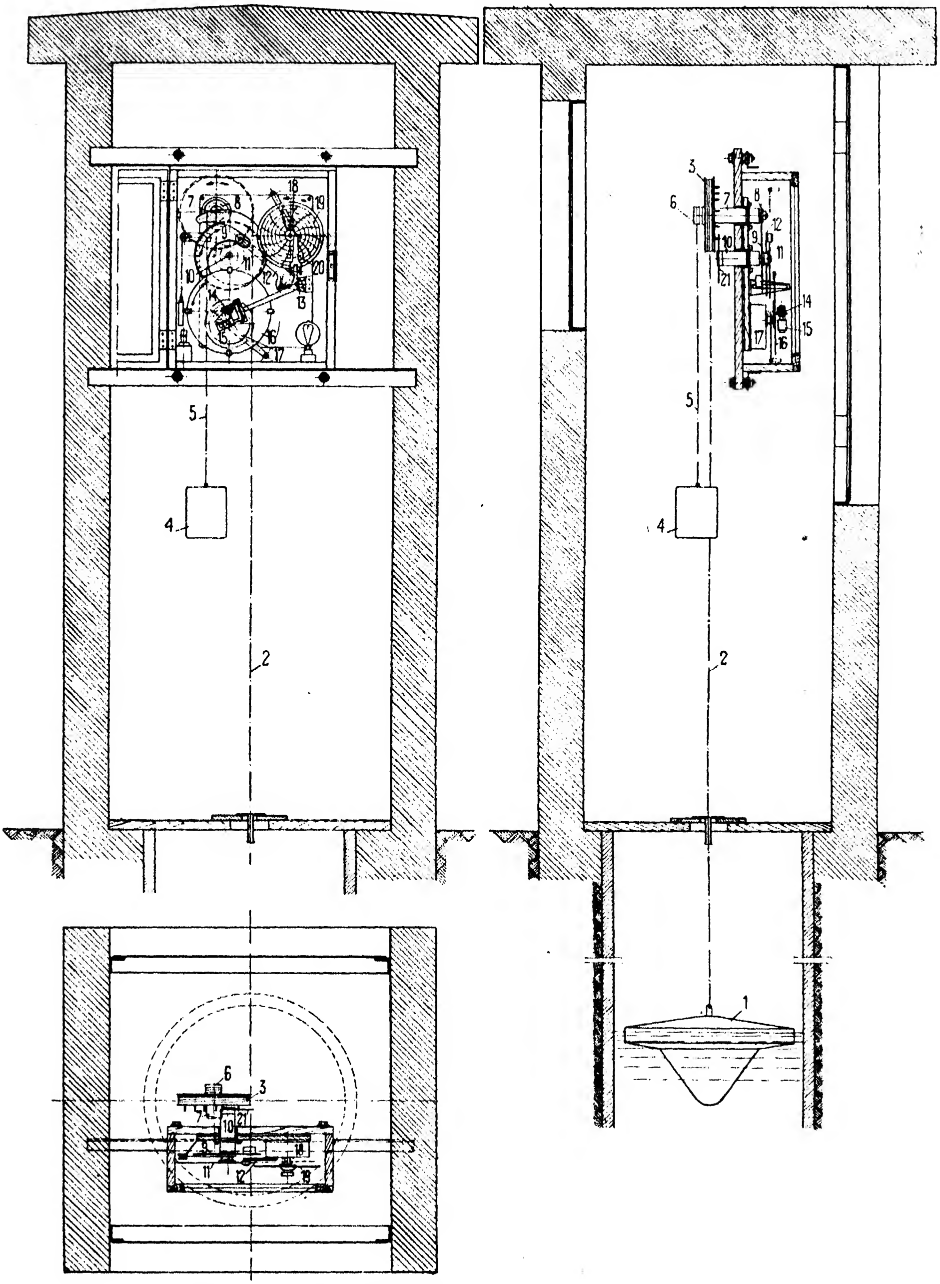


Fig. 1. Integrating Water Gauge. Scale about 1 : 20.

a water-course, and to record the variations in the flow on a diagram. The use of the gauge for determining the amount of water flowing per second by means of the height of the water is possible *only* when there is *a single, well-determined* water flow corresponding to each height of the water.

If, for instance, an open weir, as used for hydrometric measurements, is installed in the tail race of a turbine or a group of turbines of a hydraulic power station, the integrating water gauge can be perfectly well used if mounted in the tail race just in front of the weir. If, however, the water is flowing through an open channel, the flow of water per second depends at the same time upon two independent variables, that is, the height and the velocity of the water in the channel. In this case there exists no single determined relation between the water flow per second and the height of the water, and thus the gauge cannot be utilised.

The integrating water gauge consists of (1) a float which follows the variations of the water level, and (2) the integrating and recording apparatus. The float 1 (refer to Figs. 1 and 2) is attached to one end of a thin wire rope 2. The other end of this rope is wound

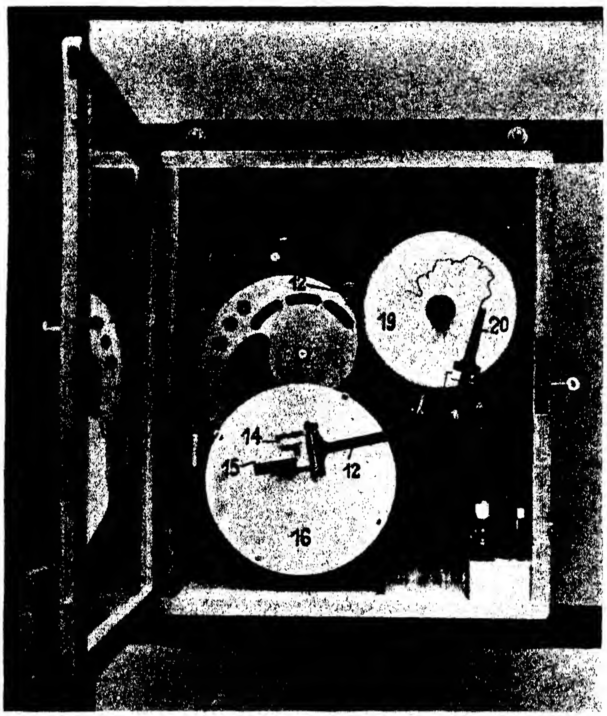


Fig. 2. Front view of instrument.

round a drum 3 fixed to the back of the instrument case. A counterweight 4, attached to the small rope 5, which is wound round a second drum 6 fixed to the same axis, keeps the float rope tight and also partly supports the float itself. The shaft 7 of the wire rope drum of the recording apparatus runs without friction in ball bearings.

When the water level rises or falls, the drum rotates proportionally to the vertical movement of the float. The friction of the rotating parts of the recording apparatus is so small as compared with the buoyancy of the float, that the depth of immersion of the float remains constant within a small fraction of a centimetre. The variations in the water level are therefore transmitted with great accuracy to the shaft 7 of the recording apparatus. On a second shaft 10, which is rotated by the first shaft by means of the gear wheels 8 and 9, rests a disc 11 having a spiral shaped edge, called the *leader disc*. A lever 12, which can turn on an axis 13, bears with a roller against this edge. This lever carries on one arm an integrating mechanism 14 and 15, and on the other a recording pen 20.

The integrating mechanism consists of a planimeter roller 14 which bears with a gentle pressure against the disc 16 rotated by a clockwork 17. The edge of the leader disc is so shaped that the planimeter roller 14, receiving its impulse by friction from the disc 16 against which it bears, is at every moment situated at a perpendicular distance from the centre of the disc which is proportional to the water flow per second, corresponding to the momentary height of the float. Thus the development of the planimeter roller 14 is accordingly the integral of the water flow with respect to the time. The tenths and hundredths of a revolution of the integrating roller 14 can be read on a vernier, whilst the complete revolutions and the tens and hundreds of revolutions are shown by a counter 15 with three totalling discs. The readings show directly the quantity of water in cubic metres (or cubic feet) which has passed the weir during a given time.

To give the proper shape to the leader disc, a diagram must be first obtained showing the relation of the water level to the water flow per second. This diagram must be secured by means of hydraulic measurements previous to the construction of the water gauge. If, for instance, the measuring weir is a single, open, rectangular notch weir, and if the hydrodynamic height $\frac{c^2}{2g}$ equivalent of the velocity of approach c is negligible in comparison to the head over the crest of the weir, then the water flow per second is given by the well-known weir formula:

$$Q = \tfrac{2}{3}\,\mu l \sqrt{2g}\,.\,h^{\frac{3}{2}},$$

where Q = the discharge in cubic metres per second;
l = the length of the weir crest in metres;
h = the head over the crest in metres;
g = the acceleration of gravity in metres per second;
μ = the coefficient of discharge as calculated from Freese's formula:

$$\mu = \left(0{\cdot}6150 + \frac{0{\cdot}0021}{h_u}\right)\left[1 + 0{\cdot}55\left(\frac{h_u}{h_k}\right)^2\right];$$

h_k = the depth of water in the approach channel, in metres;
h_u = the depth of the crest under the unaffected water level in the approach channel in front of the weir, in metres.

As the coefficient of discharge μ is comparatively not very variable over a large range of the heights h_k, h_u and as the rotation of the leading cam is in direct proportion to the water height over the weir crest h, it follows from the above formula that the shape of the cam must be approximately a semi-cubic parabolic spiral, the polar equation of which is:

$$r = \text{Constant} \times \phi^{\frac{3}{2}} + \text{initial constant.}$$
$$(r = \text{radius vector}, \quad \phi = \text{polar angle.})$$

In reality the exact form of the leading cam has to be determined in every case, point after point, from the calibration curve of the weir in question.

A separate clockwork 18 moves a second disc 19 on which a sheet of round, suitably ruled paper is fixed and on which a recording pen 20 draws a diagram of the water flow per second. The diagram disc completes one revolution in 24 hours. The paper has therefore to be changed every day, an operation which can be done without interfering with the integrating mechanism. The diagram has the value of a representative image of the regime of the water flow only, the proper measurement being effected by the planimeter roller. When changing the diagram sheet the reading on the integrating roller is taken and noted on the respective diagram sheet. The two clocks must be wound up once a week. The

diagram sheets must be specially designed and printed for each individual case in correspondence to the particular characteristics of the weir.

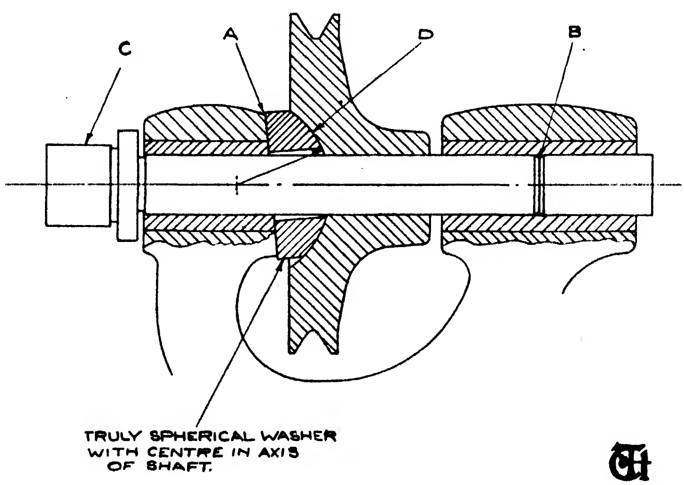
To locate the float a shaft which is connected with the water-course, the flow of which is to be measured, must be provided. The easiest way of arranging for such a shaft is to use cement or earthenware pipes of about 16 in. (40 cm.) inside diameter and to connect its lower end with the water-course by another slightly inclined pipe. The wooden case with the recording instruments should be arranged directly over the shaft and be located in a covered room. If the shaft is arranged in the open, a special small shelter of concrete, iron or wood must be erected.

An automatic stop arrangement which is actuated by the rope drum 3 prevents the instrument taking harm if the maximum top and bottom positions should be exceeded at times of abnormal water levels. This stop arrangement consists of a so-called Maltese cross 21 (similar to that used in cinematographic apparatus). As the rope drum describes several revolutions, at each revolution the cross is carried forward by one arm, and when either of the two end positions of the float is reached, the last arm of the cross engages a stop.

LABORATORY AND WORKSHOP NOTES

A NOVEL APPLICATION OF A SPHERICAL SEATING

EVERY mechanic is familiar with the use of a spherical seating where a bolt or nut has to pull up squarely on an untrue surface, but we believe the arrangement described below, in which the same principle was successfully applied to eliminate longitudinal periodic error in the spindle of a small lapping machine, designed by this company some years ago for the lapping of screw chasers, will be novel.



The chasers are centred on the cylindrical end of the spindle fitting (*C*) and clamped up against the shoulder, and, of course, as these surfaces can very readily be machined at the same time as the spindle itself, it is feasible to maintain a very precise relationship between them. Longitudinal motion to the right is prevented by the cylindrical plug (*B*) which is clamped into the rear bearing. The diameter and end face of this being machined at the same chucking, these, too, can readily be held to a high degree of accuracy, and the end face will match very nicely with that of the spindle itself.

For endwise location in the other direction, however, we must depend on the face (*A*). It is not very practicable to machine this latter, however, at the same time as the bearings

are bored, and to ensure that these are accurately square would involve expensive methods and considerable skill.

By boring out a spherical seating, however, in the face of the driving pulley (*D*), accurately concentric with its bore—and this, of course, presents no great difficulty—and interposing a spherically faced washer between this and the suspect facing, we are able very cheaply to eliminate the effect of any lack of squareness in this face—shown much exaggerated in the diagram—and we get a mechanically sound arrangement.

THE TAYLOR-HOBSON RESEARCH LABORATORY, LEICESTER.

A SIMPLE MERCURY ARC LAMP. By T. H. OSGOOD, Ph.D.,

University of Manchester.

A very simple, inexpensive, reliable and durable mercury arc lamp is described. The design and construction are not new, for the lamp has been in use for some years in America, though it appears to be little known in England. The diagram, upon which the scale is shown, is almost self explanatory. The shell is of pyrex glass;* the electrodes *A* and *B* are short pieces of tungsten† wire about 1 mm. in diameter. The seals should be made long, as shown; sodium nitrite is a good flux. In the finished seal the tungsten has a clear yellowish-brown colour.

The action of the lamp is as follows: if *B* is made positive, evaporation takes place rapidly from the surface of the mercury immediately above *B*. The vapour condenses on the cooler walls of the wide upper tube *C*, and falls back into the annular trough filled with mercury in contact with *A*, finally returning to *B* through the hole *D*. The arc is thus formed in the empty part of the lower tube. No harm can result from running the lamp with reversed polarity, though in time, all the mercury may collect in the lower tube, and the arc will go out. Starting from cold, a current of 3·5–4 amps. is necessary. After a few moments this should be reduced to 2·5–3 amps.

To evacuate the lamp the open tube *E* is connected by a piece of pressure tubing to a good oil pump, and the arc is started either by an induction coil or by heating the mercury above *B* until it jumps up into the trough and trickles back. When the lamp is thoroughly warm, and while it is still running, it is sealed off at the constriction *F*. An air-coal gas flame is hot enough for this operation. When sealed off, the arc should be mounted on a stand, clamping gently but firmly at *C*. The connections are made to *A* and *B* by soft flex and small barrel connectors. To start the lamp, it is rotated clockwise through a little more than 90° and then brought back to a vertical position.

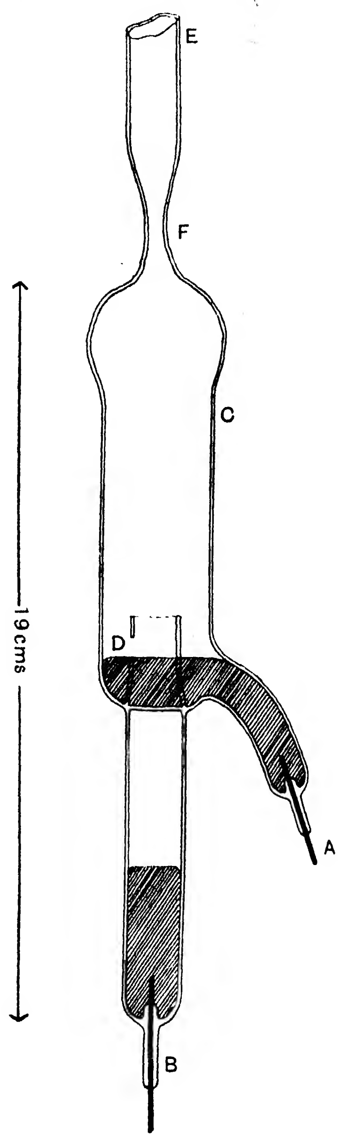


Fig. 1

* Blown for me by Messrs J. C. Cowlishaw, Ltd., 42 Bridge St, Oxford Road, Manchester.

† I am indebted to the General Electric Co. of London for the tungsten wire.

CORRESPONDENCE

LONG-PERIOD MOVING-COIL GALVANOMETERS

THE article on "A Long-Period Galvanometer" by Mr D. C. Gall in your September issue has interested me greatly, as it appears to offer a possibility of improving the moving-coil galvanometer in a direction in which it has hitherto been unsatisfactory, *i.e.* for the measurement of very low P.D.'s. My attention was first drawn to this difficulty when engaged in accurate comparisons of resistances of one ohm or less. To make such comparisons within an accuracy of a few parts in ten million, a low current in the resistances is desirable, and the P.D.'s available for deflecting the galvanometer are small fractions of a micro-volt. The resistance of the galvanometer should therefore be very low, but this is impossible in a sensitive moving-coil galvanometer, as the fine suspensions alone may have a resistance of some ohms.

But if a thick suspension were used, and some method were found of counteracting the major portion of the control, the low resistance moving-coil galvanometer becomes a possibility; and it would seem that this might be effected by drilling the supporting stem of the coil transversely and inserting a short piece of cobalt steel wire magnetized oppositely to the field of the galvanometer magnet. Mr Gall mentions that attempts to reproduce the phenomena he observed with minute magnets failed, but the present proposal is not for increasing the period of the galvanometer, but for retaining the ordinary moderate period and stability with a low resistance and therefore highly-controlling suspension. It is hardly likely that a uniform scale could be obtained in this manner, as it would probably be difficult to make the torque-deflection variation of the two controls exactly similar; but if a sensitive zero-indicating galvanometer could be produced in this manner it would have useful applications. I hope Mr Gall will pursue his investigations in this direction.

C. V. DRYSDALE.

RICHMOND, SURREY.

OBITUARY

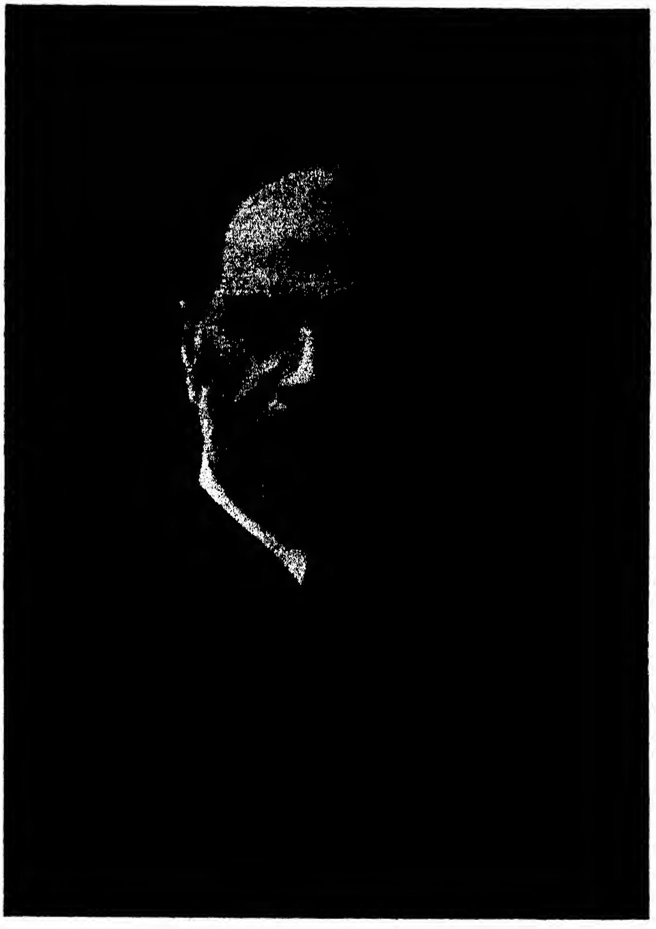
SIR HORACE DARWIN

IN the death of Sir Horace Darwin on September 22nd, the scientific instrument industry has lost one who, during the past forty years, had a great influence on the development and improvement of scientific instruments.

Horace Darwin was born at Down on May 13th, 1851, and was the fifth son of Charles and Emma Darwin. He was educated at Trinity College, Cambridge, taking his degree as a senior optime in the Mathematical Tripos in 1874. After taking his degree, he was apprenticed to the works of Messrs Easton and Anderson, an engineering firm of high repute, where he obtained a knowledge of machines and processes, which was invaluable to him all his life. It was then also that he learnt to look at many matters of works management from the workman's point of view, so that in after-life he was often able to foretell how the men in the shops would regard any steps taken by the management affecting their interests. While he was an apprentice he designed his first scientific instrument, a klinostat, for recording the rate of growth of small plants. He built the instrument himself with the aid of the works' pattern-maker, and it was used for many years by his brother, the late Sir Francis Darwin, in the Botanical Laboratory at Cambridge.

On his return to Cambridge he became interested in the work that the late Mr A. G. Dew-Smith was doing for the late Sir Michael Foster. Foster, who had recently been

appointed to the Chair of Physiology, wished to equip the laboratory with apparatus and found that, practically without exception, all the instruments required for following up the recent work on nerves, blood-pressure, etc., had to be imported from the Continent. He interested his friend Dew-Smith, a rich amateur, who invited the co-operation of Horace Darwin, and together they started to produce instruments which were at least equal, and in many cases superior, to those of Continental manufacture. A little later Darwin designed for his cousin Sir Francis Galton the series of anthropometric instruments with which so much of Galton's work was performed. With his brother, Sir George Darwin,



Sir Horace Darwin

he designed the bifilar pendulum form of seismograph for recording very small seismic disturbances. The rocking microtome, which, scientifically speaking, was the most important instrument designed by Darwin, was developed at this time.

The partnership with Dew-Smith lasted for ten years, and was then dissolved, Dew-Smith retiring, and Darwin retaining the instrument-making business. This was converted into a company, in 1895, under the name of the Cambridge Scientific Instrument Company, with Darwin the chief shareholder and Chairman. On the amalgamation of this company with the business of Mr R. W. Paul, in 1919, the name of the firm changed to that of the Cambridge and Paul Instrument Company, and later on, in 1924, into that of the Cambridge Instrument Company, Limited.

A few years before the outbreak of the War Darwin was made a member of the Advisory Committee on Aeronautics, appointed to advise the Government what researches should be made to develop the science of flight. He regarded it as his special province to design the instruments required to study the behaviour of an aeroplane or airship in flight. The War, although it brought him the greatest sorrow of his life in the death of his only son, Erasmus, who was killed in April, 1915, gave him a great opportunity. He devoted all his energies to designing instruments for the new conditions introduced by air warfare: height finders and methods of locating aircraft to meet attack by the air, gun sights, etc. In 1917 he was made Chairman of the Air Inventions Committee. In this capacity his innate courtesy and consideration for an inventor's feelings, his common sense, and his own inventive mechanical skill were of great service. That tact was required may be judged from his statement that only one in every thousand inventions submitted was worthy of serious study, and it is not an easy matter to tell an inventor that his invention is either valueless or unpractical. For his services on this Committee he was made K.B.E. in 1918.

Darwin took an active part in the town and university life of Cambridge, and was Mayor for the year 1896–7. He served on a large number of University syndicates. He was elected a Fellow of the Royal Society in 1903, and in 1919 was one of the members of the Royal Commission appointed to enquire into the administration of the Universities of Oxford and Cambridge.

Darwin's influence will be most lastingly felt in the improvements he introduced into the design and construction of scientific instruments. He was much impressed with the principles of geometric design propounded by Maxwell and Kelvin. In his designs he showed great originality; it is hoped that it will be possible in a later number of the *Journal* to deal more fully with this side of his work.

Consideration for the feelings of others and a broad charity were perhaps his chief characteristics. In a unique way he had the gift of winning the loyalty and devotion of those who worked with him.

THE BRITISH ASSOCIATION AT GLASGOW

THOSE who were in Glasgow for the recent meeting of the British Association will retain a vivid recollection of two things in that city, of the courtesy and hospitality of its inhabitants, and of the fickleness of its weather, which compared somewhat unfavourably with the fine spell in the south of England.

The scientific proceedings in the various sections, although marked, perhaps, by few communications which seemed to be of outstanding significance, included many addresses, papers and discussions of great interest. To readers of this *Journal* probably the proceedings in Section A provided the principal attraction. These included the interesting and suggestive address on the Volta effect by Professor A. W. Porter, F.R.S., the President of the Section, and the Discussions on the Mechanism of Thunderstorms, contributed to by Professor G. C. Simpson, F.R.S., and Professor C. T. R. Wilson, F.R.S.; on the Scattering of Electrons by Crystals, between Dr C. J. Davisson, Professor G. P. Thomson and others, and another on the Photographic Measurement of Radiation (Dr R. A. Sampson, F.R.S., Dr H. S. Spencer-Jones, Dr F. C. Toy and others).

Among communications more closely concerned with instrumental matters was that of Dr Ezer Griffiths, F.R.S., and Mr J. H. Awbery on the Measurement of Flame Temperatures. Dr Griffiths described two methods which have been employed at the National Physical Laboratory for this purpose. In the first, a refractory metal in the form of wire is

heated electrically *in vacuo*, and the relation between temperature and heating current determined by an optical pyrometer. The same wire is then inserted in the flame, and the relation between temperature and heating current again determined. When the results are plotted graphically the point of intersection of the two lines will give the temperature of the flame, for at the temperature represented by this point the electrical supply is sufficient to balance the radiation loss, whether the wire is *in vacuo* or in the flame, so that the surrounding gas in the flame neither imparts nor abstracts heat from the wire.

In the second method a beam of light from an incandescent tungsten sphere was focussed through the flame on to the slit of a spectroscope. Sodium was introduced into the flame, and when the temperature of the flame was greater than that of the tungsten sphere, bright sodium lines showed upon a continuous spectrum background. If the temperature were lower, reversal of the sodium lines took place. By careful adjustment of the temperature of the tungsten sphere a point was reached when all trace of either bright or dark lines disappeared. This balance could be effected within a range of a few degrees. The corresponding temperature of the sphere was then determined by means of an optical pyrometer.

Dr J. Jackson gave an interesting account of the two free pendulum clocks, Shortt 3 and Shortt 11, installed at the Royal Observatory, Greenwich, in November 1924 and May 1926 respectively. The accuracy of these clocks greatly exceeds that of earlier types, with consequent improvement of the accuracy with which time signals can be sent; but it appears that they are not yet sufficiently accurate to check small irregularities in the earth's rotation. The principal irregularities, shown by both clocks, are a temperature coefficient of 0·003 sec. per day per 1° F., and a gradual slowing down of the pendulum attributed to growth of the invar rod. The growth for the 2-sec. pendulum is about 1 micron in 120 days, producing a decrease in the daily rate of 0·037 sec. in 100 days. Dr Jackson made abundantly clear the fact that the principal requisite for the improvement of the already high accuracy of these free pendulum clocks is the discovery of a material for the pendulums of sufficient stability, more constant in its behaviour than invar.

As a contribution to the discussion on the Photographic Measurement of Radiation, Dr W. T. Astbury, of the Davy-Faraday Laboratory, gave an account of a new Integrating Photometer for X-ray Crystal Reflections. Dr Astbury has sent the following description:

In a carbon print of a negative, we have a film of gelatine which has been sensitised with aqueous potassium dichromate and made insoluble by exposure to light. This film is very tough and may be easily stripped from a temporary support. It is then equivalent in stopping power for α-rays to some 2 cm. of air, at most, and thus may be used in combination with a small deposit of polonium as a means of measuring the intensity of the radiation which produced the original negative. The α-rays pass through the film and are received into an ordinary α-ray electroscope of the Wilson type. The more intense the original radiation, the darker the spot on the negative, the thinner the carbon tissue, and the more intense the α-ray ionisation. This principle has been used as the basis of a simple integrating photometer for the spots (in general, of irregular shape, size and intensity) found on X-ray crystal photographs. Because the α-rays have a finite range, the curve X-ray intensity/α-ray ionisation may be made to ***pass through the origin***, and also, by suitable adjustments, to be ***practically linear*** over a considerable range. We have thus an instrument which substitutes α-ray intensity for X-ray intensity ***in direct proportionality***, that is, in an integrating photometer. A single slit is used—merely a hole in a thin piece of mica. The spot to be measured is placed over the hole, and then, when the necessary adjustments have been made, the rate of fall of the electroscope leaf is a direct measure of the original ***total*** intensity which produced the spot on the negative. The principle may be applied also to other radiations, such as α-rays, β-rays and light.

It is hoped to publish a full description of this photometer in a later issue of the *Journal*.

REVIEWS

An Investigation of a Rotating Radio Beacon. Department of Scientific and Industrial Research. Radio Research Special Report No. 6. Pp. vii + 45. London: H.M. Stationery Office. Price 2*s*. 3*d*. net.

In this Report Dr R. L. Smith-Rose and Mr S. R. Chapman describe the experiments carried out and discuss the results obtained in an investigation of a rotating radio beacon. Hitherto, most directional wireless transmission methods have been restricted to wireless beams which have been produced and directed either by fixed or rotating reflecting aerial systems operating on comparatively short wave-lengths. Such systems suffer from the disadvantages attendant upon the use of wave-lengths comparable with the dimensions of the reflectors. Directive reception from non-directional transmitters has been carried out by various methods, such as the Bellini-Tosi system, the Robinson system, and by using the simple rotating loop or frame aerial.

The results of using the simple rotating loop aerial for transmission is the subject of the present report. The principle of the rotating loop is briefly discussed. As the loop rotates it passes over slip-ring contacts which are so arranged that the transmitter sends out a characteristic signal each time its plane is parallel to or perpendicular to the geographical meridian. An observer with a stop-watch and an ordinary non-directional receiver is then able to time the interval between the reception of one of the characteristic signals and the reception of the minimum signal when the beacon loop will be broadside on to the observer. Thus the direction of the receiving station relative to the beacon is readily determined. The first of three appendices deals with special stop-watch dials which obviate the necessity of any calculations.

This system of transmission has been developed recently by the Royal Air Force, and the transmitter used in the present experiments was similar in design and construction to that previously in operation at the Royal Aircraft Establishment at Farnborough. The transmitter is illustrated by three photographs, but is not described, because this has already been done by Gill and Hecht in the *Journal of the Institution of Electrical Engineers*, **66**, 241. Although the original design of the R.A.F. transmitter was adopted, it was improved by the introduction of a phonic-motor, operated by an electrically maintained tuning-fork. This ensured the regularity of the rotation to within 1/100 of a second per minute.

The beacon was erected at Fort Monckton near Gosport and, although the site was not suitable for a permanent station, its abnormalities led to valuable experimental results concerning the errors arising from the proximity of land masses and other irregularities. Some of these errors can be seen from the polar curve which is given in Fig. 1 of the Report and from the calibration curve of Fig. 3.

Tests were carried out on a wave-length of 525 metres, up to a distance of 119 miles by day and night over sea and over land, at intervals of time extending for about eighteen months. Many minor results have followed from the data obtained, but perhaps the outstanding conclusion is that contained in the following quotation: "The experience gained on the various sea trips... appeared to suggest that the bearings observed on the rotating beacon have an accuracy somewhat superior to that of the bearing obtained from an estimate of the ship's position, except when the ship was in calm weather and it was possible to make a fairly accurate fix by visual means." This is the first time in the history of wireless directional work that a claim has been made to the effect that the wireless bearings are not only equal to but possibly superior to the bearings obtained by the usual navigation methods, excluding direct visual observations. This is a result of great importance, and is borne out by the fact that, on the whole, bearings up to distances of 50 miles by day or night were correct within 2°.

The detailed analysis of the various results indicate the existence of several minor disturbing factors, such as the reflection and/or refraction at coast lines; night effects for distances greater than about 90 miles and personal errors of the operator when manipulating the stop-watch. These personal errors may be as much as 2°, and therefore limit the possible accuracy of any one observation. Night effects would have been avoided had a rotating Adcock aerial been used; an improvement which Dr Smith-Rose has discussed elsewhere. Comparative tests with a Bellini-Tosi D.F. system indicate that the rotating beacon is slightly superior, especially in rough weather.

Although some reference is made to the possible variation of the polar diagram for different distances, this point would seem to require further investigation, as it is obviously important when correcting observed bearings. Such variations would have to be notified to all ships using the beacon, but this could probably be done in such publications as the Admiralty *Notices to Mariners*.

The last two appendices deal respectively with the effect of a tuned aerial on the radiation from a rotating beacon and on the results of certain screening experiments.

The general conclusion from the whole investigation is that the navigator of a ship fitted with any wireless receiver can, by means of a stop-watch, locate his position at least as reliably as he can by the usual navigational methods. This is an important result which, since it is based on a thorough and extensive investigation, should effectively dispel any mistrust felt by mariners concerning this form of rotating radio beacon.

L. S. P.

On the Relief of Eyestrain among Persons performing very Fine Work. Industrial Fatigue Research Board: Report No. 49. By H. C. Weston, M.J.Inst.E., and S. Adams, M.Sc. Pp. iv + 31. London: H.M. Stationery Office. Price 1*s*. 3*d*. net.

The investigations which form the basis of this Report were carried out upon two groups of subjects, namely persons occupied in selecting and mounting lamp filaments and those engaged in the "drawing-in" process in weaving. In both of these groups the work is so fine that in order to perform the necessary processes the operator must bring his eyes very close to the work and must therefore maintain a high amount of accommodation and convergence. Owing to the present practice in industry of keeping each worker employed solely upon one operation, persons so engaged are found to suffer considerably from eyestrain.

The method of providing relief which naturally suggested itself was to supply the workers with glasses which not only corrected their refractive errors, but also by means of positive lenses and prisms reduced the necessary accommodative and convergence efforts. Such glasses were made and the results of trials lasting over periods of several weeks were satisfactory in every case.

The authors have pointed out the difficulties of drawing definite conclusions from short trials owing to the mental reactions of individuals to changes in the conditions of work, but records of the output show that after a certain period of adaptation the output was increased by amounts varying from 8 to 26 per cent. The corrections given to the cases upon whom the experiments were made are shown in the report and it is noticeable that most of them were astigmatic. Unfortunately there appears to be no data regarding the relation of the axis of the astigmatic error to the direction of the filaments or healds with which the subjects worked. It is conceivable that under certain relations the correction of the astigmatic error may account for the major part of the improved output.

The report contains eight tables of output data, giving the results obtained from the various subjects before and after the supply of glasses, and an appendix of the comments of the subjects which were collected verbatim. Their remarks leave no room for doubt that the glasses have afforded great relief and comfort to the workers. The report should be valuable to those oculists and refractionists who may have to prescribe glasses to persons engaged in work which necessitates the discrimination of fine detail, and should also lead to an improvement in efficiency and health of a very large group of industrial workers.

E. F. F.

Probability and its Engineering Uses. By Thornton C. Fry, Ph.D., Member of the technical staff of the Bell Telephone Laboratories, Inc. London: Macmillan and Co., Ltd. Pp. xiv + 476. Price 30*s*. net.

A complete treatise on probability must deal with three distinct questions. First, what does probability mean, and what fundamental assumptions must be made about it? Second, what mathematical methods are appropriate to the development and use of these assumptions? Third, what important applications can be made of them? Dr Fry's treatise is complete in that it discusses all these questions. Its title might suggest that the third was the author's main concern and that the section dealing with it would be the longest and strongest.

Such expectations would not be fulfilled. Only two chapters are concerned with specific applications. One is on telephone traffic, a problem that affords excellent examples of the various mathematical methods, but is otherwise of little interest to the general engineer. The other treats of classical kinetic theory and the Schottky effect. A writer is often wise to select as examples matters within his own special sphere; but here, if the part played by probability in pure physical theory was to be discussed at all, it might have been preferable to choose matters of more topical interest, which would justify better the title "Fluctuation phenomena in physics."

In discussing the second question, that of the mathematical theory, Dr Fry is at his best. He does not condescend to "engineering mathematics," but insists on rigid proofs; yet his methods are always straightforward and there is no striving after elegance at the expense of lucidity. It might have been better to separate general analytic methods from particular problems; but almost all the mathematical apparatus required in applications of probability will be found well expounded in some part of the book.

The first of the three questions is certainly the most difficult, for it is to some extent controversial. There is much more agreement about the values to be assigned to the probabilities of specified events and about the practical conclusions to be based on those values than there is about the reasons for their assignment. It is easy to define probability so that the mathematical theory is true; it is not difficult to define it so that probabilities can be estimated empirically and so that propositions about them have practical significance; but it is difficult to do both. A reviewer must not allow himself to be prejudiced because the solution of the difficulty adopted by the author is not his own; but perhaps he may demand that the author should adopt one of two courses. Either he may choose some definition that gives a clear answer to all the questions he is going to ask; then he should eschew paradoxes. Or he may indulge in intellectual subtleties; then he should recognize other views and not be dogmatic. Dr Fry seems to us to be dogmatic and yet paradoxical; controversial yet limited; subtle and yet sometimes obtuse. He can hardly dismiss Poincaré and M. Borel as mathematically incompetent; yet he makes no reference to the views of the latter and little to those of the former. He refers to Mr Keynes, and is apparently influenced by his work; yet he omits to point out that, while he makes probability a property of an event, Keynes regards it as a property of a proposition. Is it worth while to puzzle his readers with questions about the probability of life on Mars, while he omits to draw their attention to so vital a distinction?

To sum up, Dr Fry's book bears the imprint of his personality; it is original and stimulating; everyone will find something fresh and important in it. But it is not the whole truth, and it is not milk for babes; the author was indeed fortunate if the engineering students, to whom it was primarily addressed, were capable of appreciating it.

N. R. C.

CATALOGUES

Messrs Bellingham and Stanley, Ltd., 71, Hornsey Rise, London, N. 19, send a new catalogue of Spectrometric Apparatus, including particulars of a simple quartz spectrograph which has been specially designed for industrial spectrum analysis, and which is sold at the exceptionally low price of £18. 10*s*. 0*d*. The catalogue gives also particulars and prices of other spectrographs and accessories for spectrographic work. A separate pamphlet describes a new spectrocomparator which the firm has recently introduced.

The Leeds and Northrup Company, 4901, Stenton Avenue, Philadelphia, U.S.A., send the latest addition to the excellently produced series of publications relating to their manufactures, "Catalog No. 80, Resistance Thermometers." In the catalogue, which is fully illustrated, the extensive range of apparatus made by the company for controlling, recording and indicating temperatures is described. Much useful information in relation to the technique of resistance thermometry is also given, and we notice a list of Definitions of Pyrometric Terms recommended for general use by the Industrial Group of the Association of Scientific Apparatus Makers.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V | NOVEMBER, 1928 | NO. 11

ULTRA-VIOLET MICROSCOPY.

By L. C. MARTIN, D.Sc. Assistant-Professor, AND B. K. JOHNSON, Demonstrator in the Technical Optics Department, Imperial College of Science and Technology.

[*MS. received*, 30*th June*, 1928.]

ABSTRACT. The paper describes experiences encountered in trials of various methods of ultra violet microscopy. The selection with the aid of the interferometer of the fused quartz for the objective; the arrangement of the illuminating systems; old and new methods of finding the ultra-violet focus; the mechanical requirements of the microscope; the control of the immersion fluid by the use of non-hygroscopic mixtures, and the investigation of the resolving power of ultra-violet systems, are among the subjects discussed.

THE renewed interest in the possibilities of ultra-violet microscopy, to which attention has been drawn in recent years by the work especially of Barnard in England, and Lucas in America, made it appear that the question was one which might be taken up with profit by the Technical Optics Department of the Imperial College of Science and Technology, with a view to providing instruction in the technique of this, the main hope of obtaining greatly increased optical resolving power. It was the intention that some of the incidental problems should be studied with a reference to the possibilities of simplifying and improving the practice, and also with a view to examining the practical advantages which can be attained.

The microscope "stand" selected for a beginning was one constructed by Messrs R. & J. Beck, Ltd., from the design of Mr J. E. Barnard, F.R.S. An iron casting of great rigidity supports the substage, the stage, and the focusing unit. A full description of the apparatus is being published by Mr Barnard, but it may be mentioned that the object of the design, while providing the necessary stability and rigidity, is to permit of the process of finding the ultra-violet focus by first placing a visual apochromat in the objective changer and finding the visual focus, then substituting the monochromat lens employed for the ultra-violet and changing the focus by a predetermined amount.

In the fine adjustment of the focus the objective is carried on a bracket which is mounted on a very accurately made slide and moved by a special micrometer screw of 1 mm. pitch. The fine adjustment is effected by a tangent screw, of which one turn rotates the main screw through 0·01 revolution. The milled head of the tangent screw carries a drum divided into 100 parts, so that one division on the drum represents a motion of the objective of 0·0001 mm. Naturally the bearings of the screw have to fulfil an exceedingly exacting demand to do justice to a motion so fine.

Let U be the angular semi-aperture of the cone of rays entering the monochromat objective, then a trustworthy expression for the depth of focus in the object space is

$$\delta s = \lambda / 4N \sin^2 (U/2).$$

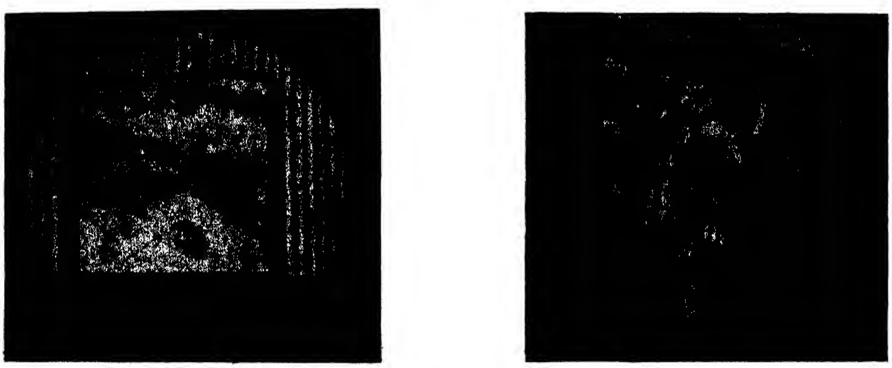
For three objectives corresponding to the monochromats listed by Zeiss we can find the following figures:

Table I

Focus (mm.)...	6·0	2·5 (immersion)	1·7 (immersion)
NA	0·35	0·85	1·25
Depth of focus (object space)	2·2 μ	0·52 μ	0·2 μ
Depth of focus (image space)	1·2 mm.	1·2 mm.	1·2 mm.

With the highest power lens the depth of focus in the object glass corresponds to two divisions of the drum; the theory is confirmed by experience. The depth of focus in the final image (received on the plate) depends on the focal length of the projection eyepiece; one with 16 mm. focal length used with a nominal camera length of 30 cm. gives a depth of focus extending from about 19 cm. up to 100 cm. or more. While, therefore, the plate must be fixed extremely rigidly in relation to the microscope, it is entirely on account of the fineness of the definition and not on account of any small depth of focus in the camera.

It was decided to entrust Messrs R. & J. Beck, Ltd., with the manufacture of an immersion monochromat objective, but the fused quartz intended for this purpose was previously



(*a*) Front view (*b*) End view

Fig. 1. Interferograms of fused quartz block. 25 mm. square × 16 mm. thick

examined by us on the interferometer. Fig. 1 shows the first interferograms taken in two directions at right angles through the specimen. The regions of non-homogeneity were cut away and a second pair of interferograms permitted the selection of the best portions of the block for the lenses. It seems, however, as if all available specimens of fused quartz show a residual grain which is just visible in the interferometer and is therefore bound to produce a certain deleterious effect in the image, more especially with the ultra-violet radiation.

General lay-out of Apparatus

The general lay-out of the apparatus will be seen from Fig. 2 and consists essentially of the microscope unit M and two illuminating systems VK and GP. The former consists of a mercury arc for visual observation (either central or dark ground illumination), whilst the latter is the cadmium spark and monochromator for giving the ultra-violet illumination. Other parts of the apparatus are C = camera; F = fluorescent eyepiece; T = exposure shutter.

The arrangement of the components is in general similar to that used by Barnard*, with the exception that in this case the parts are mounted in geometric fittings on a stout and well-made table of teak, which was sufficiently large to allow of the changing of positions

* In Barnard's apparatus the various parts are mounted on a massive bed-plate casting.

of the illuminating systems in order to use the instrument for "vertical illumination" as well as with "transmitted light." In order to secure reasonable freedom from vibration, the table was suspended by steel springs from an outer framework, whilst small side springs preserved its lateral stability. This will be made clear from Fig. 3, in which *T*, *O*, and *S*

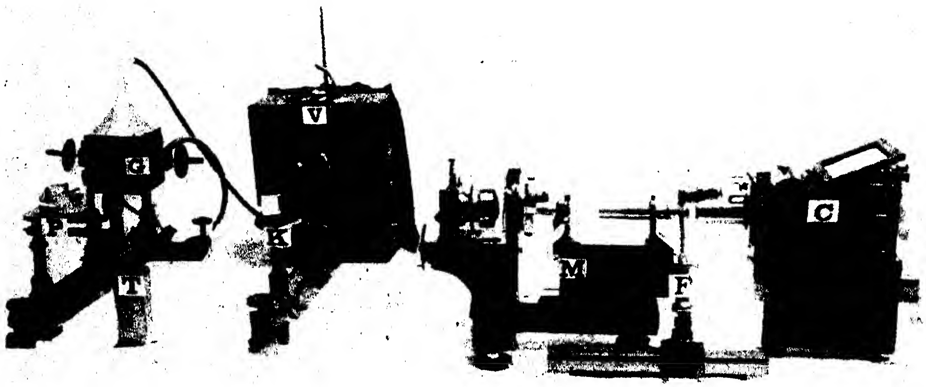


Fig. 2. General view of apparatus

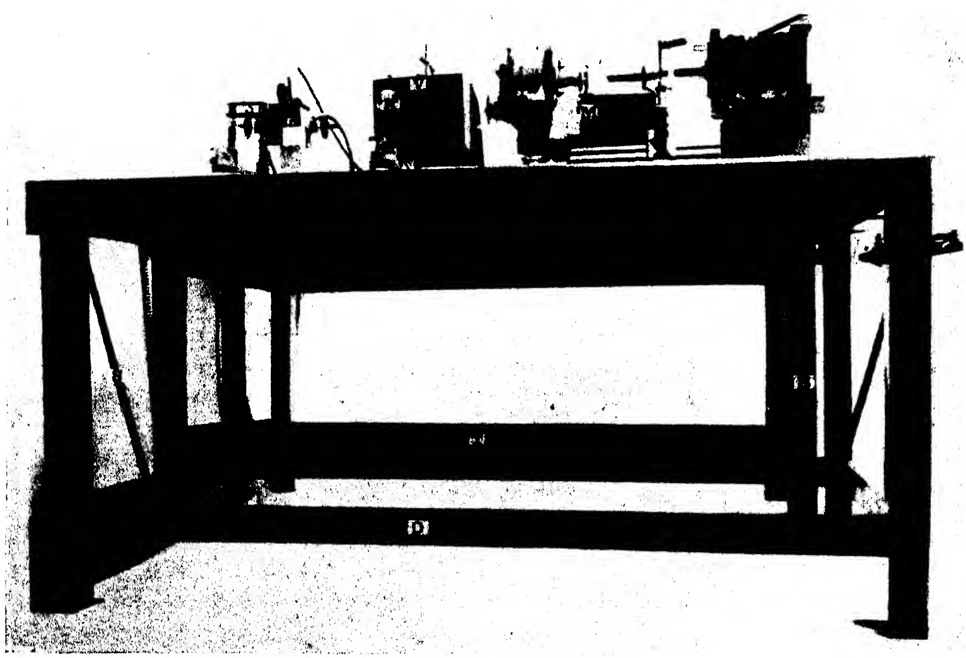


Fig. 3. Showing suspension of table

refer to the table, outer framework, and springs respectively. The present Technical Optics laboratories were adapted from rooms not primarily intended for laboratories and somewhat subject to vibration. Hence this precaution is very necessary.

A plan view of the table (Fig. 4) shows how geometric design (in this instance, the plane, slot, and hole principle) has been used with advantage for the quick transferring and precise

positioning of both the illuminating systems and the cameras when used in their alternative positions. The fact of being able quickly to remove the camera away from the microscope is convenient and to be recommended. In order to reduce flexure of the microscope stand to a minimum, the two feet at the front of the instrument, instead of being fixed rigidly to the base, can each be replaced by a steel ball rolling in its geometric fitting.

It has been found advantageous to have the spark gap enclosed in some form of housing similar to that shown at G, Fig. 2. This not only screens the eyes from harmful radiations, but the objectionable cadmium vapour can be drawn off by suction—in this case by means of a small filter pump attached to the water supply. The housing also tends to deaden the noise of the spark, a point which is worthy of consideration when using the apparatus over prolonged periods. It is desirable to have the entire equipment of the ultra-violet microscope in a darkened room, as it is difficult to carry out the necessary adjustments without

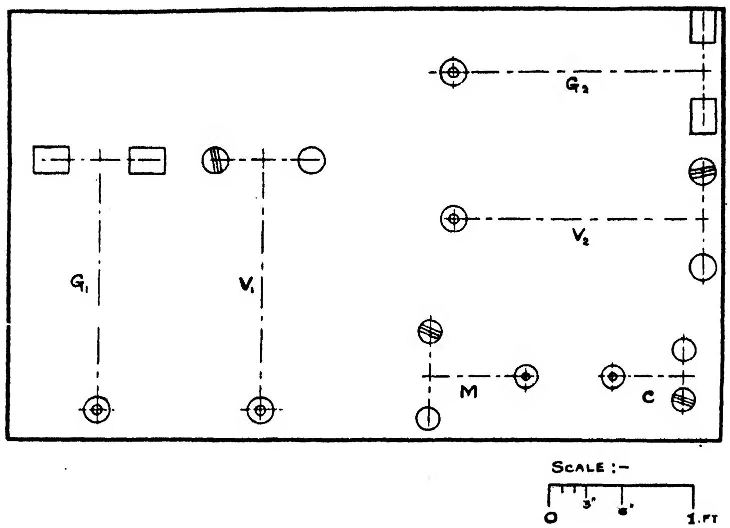


Fig. 4. Plan view of table to scale

M = microscope base. C = camera base.
V_1 and V_2 = alternate positions of mercury arc illuminator.
G_1 and G_2 = alternate positions of Cd spark illuminator.

this, owing to the low luminous intensity of the images that may have to be dealt with. It was convenient to mount a "slit," with jaws ground from quartz, immediately in front of the spark. This helps to make the spectrum more definite when tests are made with a fluorescent screen to check the adjustment as regards the projection of a special "line" into the condenser.

Electrical Installation

A small "pack-type" Marconi set of a half-kilowatt transformer and condensers was employed, the capacity being about 7200 cm.; the current was supplied by a small alternator capable of giving 5 amps. at 100 volts (100 cycles per second). In this way a sparking potential of the order of 10,000 volts could be obtained. The set contains a few turns of thick wire for providing self-induction in the secondary circuit; this is quite sufficient to remove the air lines from the spectrum. The equipment has proved very reliable, but much higher frequency could be used with advantage. The spark gap used is usually approximately 4 mm.; each cadmium pole (made from a piece of rod 6·5 mm. in diameter) is

filed to an edge, the apex angle being about 90°; poles are renewed when necessary. A fairly steady spark has been easily maintained between the parallel edges of the poles.

In practice the volts across the primary of the transformer are approximately 90 when running, the primary current being 3·7 amps. A number of rheostats are included in the primary circuit so that the discharge is started by reducing the external resistance from 156 ohms to 22. The primary voltage may run up to 120 just before the discharge com mences.

The frequency attainable with our alternator is unfortunately low; it is estimated by the makers that the transformer would be quite safe up to a frequency of 500 cycles at 100 volts, and if frequencies of this order could be provided the apparent luminosity of the discharge would increase accordingly, thus shortening the exposure.

Illuminating Systems

Fig. 5 shows diagrammatically the illuminating system for the microscope when used for transmitted light. The light passes through the monochromator $L_1P_1P_2L_2$—these components being of crystalline quartz—and the spectrum thus formed is brought to a focus

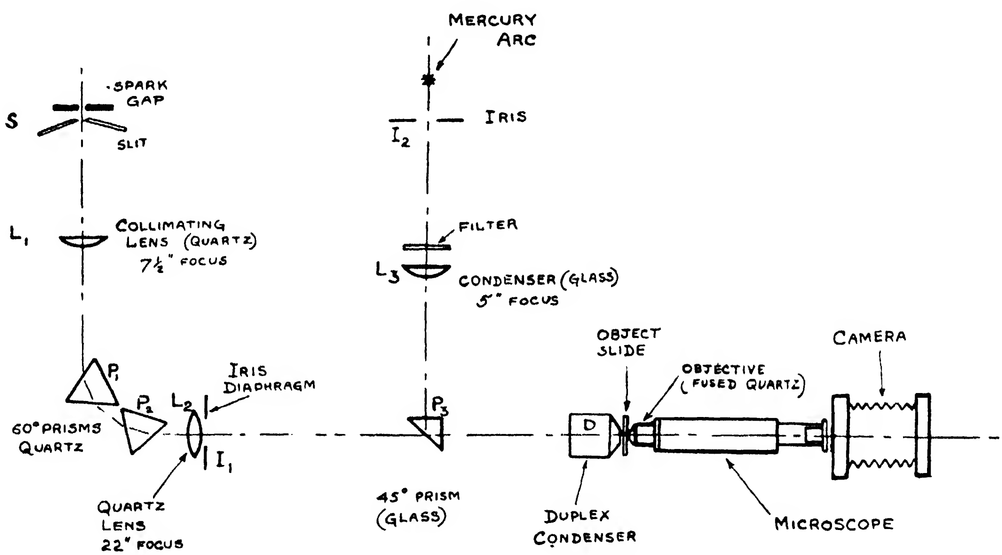


Fig. 5. Illuminating system for ultra-violet microscope. (Diagrammatic)

in the plane of the microscope condenser D, and so adjusted that the 0·275 μ Cd line completely fills the central aperture of the "duplex" condenser*. An iris diaphragm placed immediately behind the lens L_2 serves as the effective radiant, this being focused in the plane of the object by the condenser.

The mercury arc, together with a filter, a lens L_3, and prism P_3 provide the means for illuminating the object with visual (monochromatic) light. The right-angled prism P_3 can be conveniently swung out of position when the ultra-violet illumination is required. The writers are inclined to think, however, that, apart from dark-ground illumination, this portion of the apparatus might be dispensed with in some cases, and a simple "Fullolite" bulb substituted at position I_1 (Fig. 5), as present developments indicate that it is no longer necessary *always* to find the numerical focus with an auxiliary objective in visual light.

* *Lancet* (July 18, 1925) 109.

Fig. 6 illustrates the apparatus as arranged for use with the vertical illuminator (*i.e.* for opaque objects). In this case the $0{\cdot}275\mu$ line of the Cd spectrum is brought to focus by means of the monochromator in the plane of the lens L_3, which, together with the iris I_2, is situated at the same distance from the vertical illuminator as the primary image produced by the microscope objective. The quartz lens L_3 forms an image of the iris I_1 on the back lens of the objective, whilst an image of I_2 is formed in the plane of the object by means of the objective; both iris diaphragms can be varied in diameter to obtain the most favourable conditions of illumination.

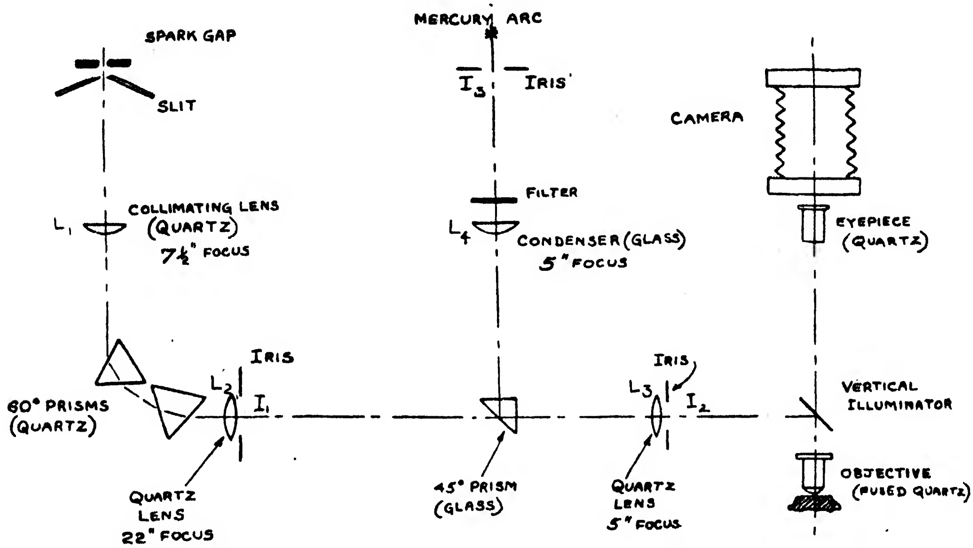


Fig. 6. Illuminating system for ultra-violet microscope.
Vertical illuminator method—diagrammatic

Vertical Illuminator Plate

The selection of a suitable reflecting plate (*i.e.* a vertical illuminator) of sufficiently good optical properties for this work is of importance, as indeed it is for use with high-power objectives in visual light. The surfaces of such plates should be optically worked for the attainment of best results, but even so their thinness makes it difficult to hold them in a mount without their surfaces becoming distorted; moreover in the case of ultra-violet illumination limitations are at once placed on the use of material for this purpose owing to the few substances which will transmit the $0{\cdot}275\mu$ region even in small thicknesses, and which are at the same time sufficiently homogeneous. Of these, crystalline quartz and selenite appeared the most hopeful, but examination in the interferometer of two such plates (optically worked) indicated the great difficulty of obtaining plates which are of sufficiently good optical quality to bear placing in the path of the image-forming light. The difficulty was finally overcome by employing a methylated collodion film stretched over the end of a 1 in. diameter tube which had been cut off at 45°. Such a film, mounted on a relatively large frame, gives a central area which has excellent optical qualities, and besides the fact of transmitting the ultra-violet region, it has the advantage of being so thin that no doubling of the reflected image in the microscope occurs, as in the case of a relatively thick and usually prismatic plate.

These films may be conveniently made by pouring the methylated collodion (diluted with ether) on to a glass plate and allowing to dry. The film can then be floated off on to water, where it may be picked up on to the desired framework by placing the latter (whose

surfaces have first been treated with an adhesive material such as liquid shellac) carefully in contact with the film and mopping up the edges on to the tube with a small brush. The whole may then be lifted from the water surface with a careful "sweeping" motion.

Focusing Source in Plane of Object

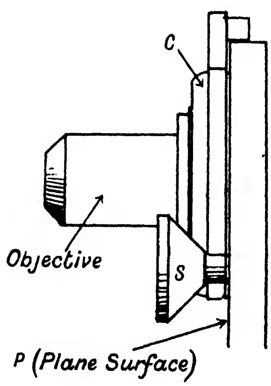
The utilization of the full aperture of the objective usually demands that the radiant or effective radiant be focused in the plane of the object under observation. The two following methods for ensuring this condition with ultra-violet illumination were devised.

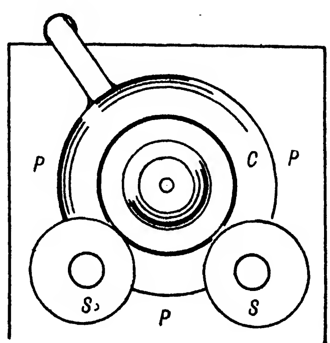
The first consisted in locating the object plane by placing a piece of uranium glass in contact with a quartz slide situated on the stage of the microscope, and whilst observing this plane with an auxiliary low-power glass objective in the microscope, the condenser can be adjusted so that an object (such as a pencil or piece of wire) placed in the plane of the iris I_1 (Fig. 5) is brought into focus. Having done this for a known thickness of the quartz slide, the fine adjustment of the condenser (which has a divided drumhead) can be calibrated for any other thickness of slide. Hence, when a new object—already mounted maybe on a slide with cover glass cemented on—is to be used, it is only necessary to measure the thickness of the slide, say at its corners, and set the condenser accordingly.

The second method employs the use of the fluorescent eyepiece as in the case described for focusing the object (see below). If it be assumed that the object is focused with the fluorescent eyepiece, an opaque object $\frac{1}{8}$ in. wide is then placed over the centre of the iris I_1, and the condenser adjusted until its image is simultaneously in focus with the object.

Determination of Ultra-violet Correction from Visual Setting

The objectives for high-power work, both the monochromat and the apochromat, are screwed into circular collars C (Fig. 7), the plane surfaces of which are in contact with the planed surface of the objective carrier P; the "registration" is secured by contact of the





(a) Side view (b) Front view

Fig. 7. Mount for objectives

rounded shoulder of the collar against the inside of two steel cones, S. The objectives are nearly of the same length, and the mounts or collars were finally ground by us until they agreed in focus within 20 drum divisions.

In order to find the correction between the visual and ultra-violet foci with the "transparent" types of object, which were the only ones at first available, a film camera was mounted in place of the plate camera, and a screen with an aperture 1 in. wide was placed in front of the film. Thus more than 20 exposures could be obtained on a spool of film by moving the film 1 in. at each exposure.

The object (a slide of "Navicula rhomboides") was first focused with the apochromat ("mercury green" light as illuminant) and the mean position of focus found from six readings. The ultra-violet illumination was then brought into action and a series of 20 photographs was taken on the film with a common interval of 20 drum divisions. The exposure was 20 seconds. The appearances with the fluorescent eyepiece were very indistinct, and only served to fix the range over which the photographic exploration was carried. The figures were:

Mean visual focus (apochromat) 6·94758.
Range of 1st film (interval 20 divisions) 6·94–6·978. (Focus not on this film.)
Range of 2nd film (interval 20 divisions) 6·96–6·998. Focus (approximate) 6·984.
Approximate correction = 0·038.

The rough correction to the visual focus was thus found from two films. Since the visual setting was likely to have changed, the focus was again found with the apochromat, and we obtained, after having cleaned and replaced the slide,

Visual focus (apochromat)	= 6·95408
Add approximate correction	= 0·038
Expected ultra-violet focus	= 6·99208

Film 3 (interval five drum divisions) 6·985–6·9950. This film gave sharp focus for exposure 12 (drum reading 6·9905). This reading having been found on developing the film while the objective and slide were still in position, the drum was set to 6·9905 and (the plate camera being substituted) two satisfactory photographs of the diatom were obtained at 6·9905 and 6·9906.

Subsequently to this, the ring mount of the apochromat was ground down still further to reduce the difference of the visual and ultra-violet readings, but no serious difficulty was ever experienced in finding the ultra-violet focus with the film; difficulties were, however, met with at first in using the correction found from the film to obtain photographs on plates.

Determination of the Tube-length for the Objective

The diatom is an unsatisfactory object for the first trials, and as soon as possible some ilver film objects were made by depositing enough silver on one or two fused quartz cover glasses to get a film, not too opaque, and with plenty of small holes. One of the writers* has described the extra-focal images obtained with such pin-holes in the presence of spherical aberration; by taking films of the object and its extra-focal images in finding the ultra-violet focus and correction at different tube-lengths, it was easy to recognize the diffraction patterns characteristic of under-corrected or over-corrected spherical aberration, and to make a choice of the best condition. It may be mentioned that "gaps" in the silver film gave very easily focused images in the fluorescent eyepiece, and the setting for this focus generally proved to be identical with the photographic focus within the limits of error of observation.

Table II

Tube-length mm.	Correction from visual focus
160	+ ·0030
167	+ ·0014 (best tube-length)
170	− ·0003
180	− ·0014

* "A physical study of spherical aberration." *Trans. Opt. Soc.* **23** (1921–2) 63.

(To be continued)

THE PILOT BALLOON SLIDE RULE.

By F. J. W. WHIPPLE, M.A., Sc.D., F.Inst.P.

[*MS. received, 11th July, 1928.*]

ABSTRACT. The slide rule designed by the author for the reduction of pilot balloon observations has recently been modified by the provision of additional scales which come into use when the "tail method" is adopted. The special features of the rule are described.

The velocity and direction of the upper winds are usually determined by meteorologists from observations of the movement of small rubber balloons filled with hydrogen. Balloons used for this purpose are known as pilot balloons. The balloon is followed with a theodolite of the type introduced by A. de Quervain in which the light is reflected in such a way that the eyepiece of the telescope is always horizontal.

Three methods of observation are in use. The simplest is the single theodolite method which is based on the knowledge that if a balloon of known weight is filled until it is sufficiently buoyant it will ascend with a velocity which is fairly constant and which can be prearranged. In British practice it is usual to fill the balloon for a rise of 500 feet per minute. Knowing the height of the balloon at the end of so many minutes and having observations of its bearings, we can compute the position of the balloon in space and so estimate the strength of the horizontal components of the wind.

The second method is to use two theodolites at the end of a base line. Simultaneous observations give the position of the balloon in space and no assumption as to the rate of ascent of the balloon has to be made. The observations can be used in fact for estimating the strength of the vertical currents as well as the horizontal ones. The only drawback is that the greater elaboration requires additional staff for the work. The third method is the tail method, in which only one theodolite is used, but the eyepiece of the theodolite is provided with a scale by which the apparent length of a tail suspended from a balloon is measured. The three observations, azimuth, elevation and angle subtended by the tail suffice theoretically for determining the position in space of the balloon. The principal difficulty is introduced by the oscillation of the tail.

The computations required in any of the three methods are quite simple, but they are very numerous, as triangles have to be "solved" by the hundred. Several methods of dealing with the computations, many of them graphical, have been devised. There are, however, numerous advantages in using the slide rule for such a purpose; an ordinary slide rule will serve provided that the sines and tangents are referred to the same base. (In most rules the scales with which sines and tangents are compared are not the same.) There are, however, features in pilot balloon work which make it desirable to use a special rule.

In the first place, the angular co-ordinates of the balloon change but little from one observation to the next, whilst the linear co-ordinates change considerably. It is, therefore, advantageous to have the trigonometrical scales fixed and the linear scales movable. Two sine scales are required as the sine and cosine of the same angle must be indicated by cursors simultaneously. Further, there must be three cursors at least to work on the trigonometrical scales; and the cursors must be made so that those on opposite sides of the rule may pass each other readily. These features were all introduced in the original pilot balloon slide rules which were made in the year 1915 and are described briefly in the *Computer's Handbook*, Sect. 2, p. 19, Subsection 1 (1915). These rules were provided with double slides which were intended to allow for variations in the assumed rate of ascent of the pilot balloons.

When the practice of adopting standard rates of ascent was adopted, the extra slide became unnecessary and observers using the old rules now lock the slides together*.

In recent years the use of the tail method has become more general and it became desirable to introduce an additional pair of scales to facilitate the new type of calculations. These extra scales are incorporated in the new rules (Mark II) now issued by the Meteorological Office. The illustration (Fig. 1) represents the rule of the new pattern. Its length when closed is $24\frac{1}{2}$ inches.

It will be noticed that the ordinary logarithmic scale on the slide extends from 1 to 10^3. One of the sine and cosine scales extend from 0·5° to 90°, the other from 10° to 90°. As may be seen in the enlargement (Fig. 2) the degrees from 0° to 20° on each cosine scale are shown along a little arc instead of being crowded together as in the ordinary slide rule. The tangent scale extends from 3° to 84° instead of being cut off at 45°. The two new scales required for the tail method are a "graticule" scale which runs the opposite way to the other logarithmic scales, and a scale showing the square of the secant; the interval between 40° and 50° on this scale being twice that between 40° and 50° on either of the upper scales. The cursors used on the new rule were designed by Mr L. H. G. Dines so as to run as smoothly as possible whilst keeping the cross lines close to the face of the rule.

The reason for the use of a scale giving the square of the secant will be seen on consideration of the equation giving r, the horizontal distance of the balloon in terms of L, the length of the tail, E the elevation of the balloon as seen in the theodolite and ϵ the angle subtended by the tail.

Since the angle ϵ is small we may write,

$$L = r\,[\tan E - \tan (E - \epsilon)] = r\epsilon \sec^2 E$$

and it follows that,

$$r = \frac{L/\epsilon}{\sec^2 E}.$$

Instead of ϵ the computer knows m the reading of the graticule in the eyepiece of the theodolite. The number of units on the graticule scale equivalent to one radian (say K) is given, so that the critical equation is equivalent to

$$r = \frac{C/m}{\sec^2 E},$$

where $C = LK$.

It has been found convenient to use 120 feet tails for pilot balloons and graticules for which $n = 10^3$. Accordingly the value $C = 12 \times 10^4$ has been adopted as the standard in designing the pilot balloon slide rule.

The object of the balloon observations is to determine x, y, z, the horizontal and vertical displacements from the value of the azimuth A, the elevation E and the graticule reading m. The unknowns are given by the equations,

$$\frac{x}{\cos A} = \frac{y}{\sin A} = \frac{z}{\tan E} = \frac{C/m}{\sec^2 E}$$

and the settings of the four cursors and of the slide indicate the equality of these four ratios.

The settings of Fig. 1 are shown diagrammatically in Fig. 3. In this case the elevation of the balloon is 21°, the azimuth is 28° and the graticule reading is 6·6. From the readings of the cursors it is found that the height of the balloon is 6100 ft. whilst the distances to north and to east are 14,000 ft. and 7400 ft. respectively. In practice the horizontal distance

* Meteorological Office, Publ. No. 223, *Computer's Handbook*, Sec. 2, Subsec. 1. Second edition, 1920, p. 12.

Fig. 2. The cursor and the ends of the sine and cosine scales. (Natural size.)

Fig. 1. The pilot balloon slide rule Mark II.

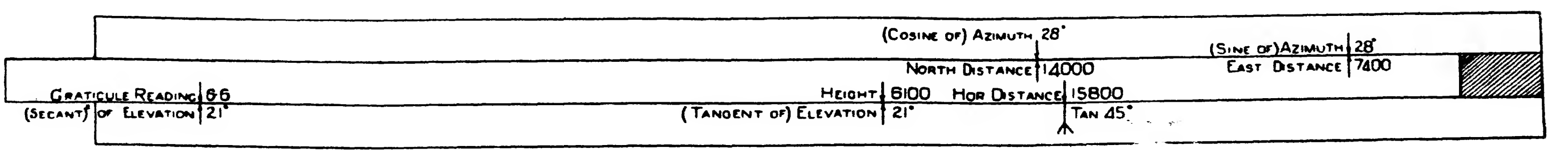


Fig. 3. Settings of the slide and cursors.

of the balloon is not usually required but it can be read on the slide against the "tan 45°" on the lower scale. In the illustrations the distance is 15,800 ft.

In the simple one-theodolite method, the value of z is known from the time and the rate of ascent. The settings of three cursors and of the slide suffice to determine x and y. The important elements from the meteorological point of view are not x and y but their changes minute by minute. These changes give the horizontal components of the wind's velocity. In British practice, the wind velocity in miles per hour is read off from a table in which the components are given in feet per minute. Whilst the observer makes theodolite readings every minute his assistant is able to make the necessary calculations between the observations so that results are available very shortly after the end of the ascent.

The pilot balloon slide rule can also be used for the two-theodolite method, and it is found useful in other work in which much elementary trigonometry is involved. Whilst it is possible to use the rule for mere arithmetical operations it is not so convenient for such purposes as the ordinary rule.

TESTING INSTRUMENTS FOR YARNS AND FIBRES. By

WILLIAM S. DENHAM, D.Sc., F.I.C., and THOMAS LONSDALE, M.Sc., F.Inst.P. (British Silk Research Association.)

[*MS. received, 30th June,* 1928.]

ABSTRACT. 1. A ballistic instrument for measuring the work done in breaking a thread or bundle of filaments is described. The thread is mounted between two clamps, one of which is incorporated into a pendulum at its centre of percussion, the other rests on a ledge on the pendulum, the instrument being contrived so that this clamp is caught on fixed projections when the pendulum is at the lowest part of its swing. The energy absorbed in breaking a thread is measured in terms of the consequent decrease of the arc of swing of the pendulum after falling from a definite height.

2. The extensometer described gives load-extension diagrams of single ultimate filaments of silk. Tensions on the filament under test produce torsions on a steel blade; these are recorded by the consequent deflections in a vertical plane of a beam of light which falls on a photographic film. The elongations of the filament corresponding to these tensions are proportional to the (corrected) horizontal movements of this film, which records load-extension diagrams with rectangular co-ordinates.

The instruments for testing fibres and yarns which are described in this note, namely, an instrument for ballistic tests and a recording extensometer, were designed in the Laboratory of the British Silk Research Association.

1. Ballistic Instrument

This is an improved form of an instrument described in the *Journal of the Textile Institute** which was designed for the comparison of the work done or energy expended in breaking fibres or yarns under similar conditions. As pointed out by Lester† the work done in breaking a yarn may be a better measure of the textile properties of a yarn than its breaking load. Moreover, when a bundle of threads is broken the total work done is additively composed of the work done in breaking each thread; the breaking load of a bundle of threads on the other hand may not be an additive quantity owing to inequalities in the tension and strength of the individual threads of the bundle. The additive character of the work done is particularly useful in comparing samples of loose fibres or filaments such as those of silk,

* **15** (1924), T 291.

† *Journ. Text. Inst.* **1** (1910) 70.

and in following the effect of various treatments of such samples, for sufficiently representative values may be obtained by breaking, say, 1000 to 2000 filaments in 10 to 20 tests, each test made with a bundle of 50 to 100 filaments, whereas the comparison would be impracticable if such numbers of filaments had to be manipulated and broken individually. It is not claimed that absolute values for the work done are obtained by this instrument; but the values of measurements made similarly are comparable. The measured amount of energy consumed is proportional to the number of similar threads or fibres broken at one time, and is equal to a quantity proportional to the length of thread broken plus a small constant quantity.

General Description

The instrument (Fig. 1) consists of a pendulum fitted with a device for recording the height of swing and with a clamp at its centre of percussion for securing one end of the

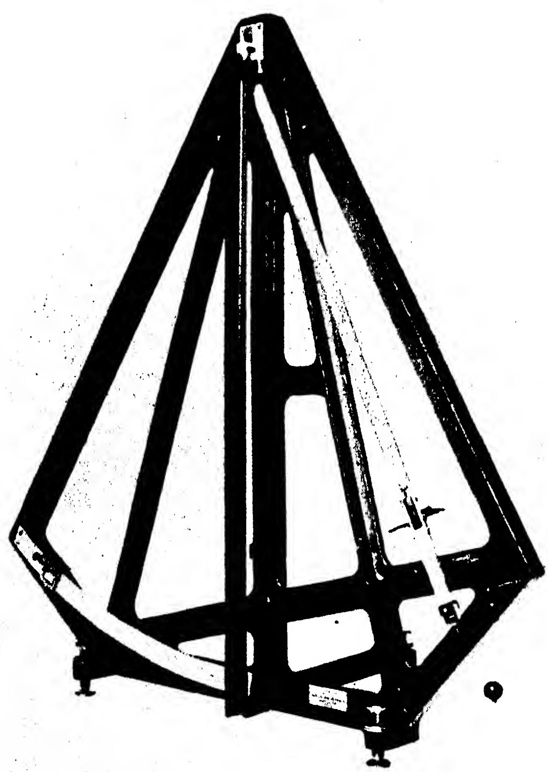


Fig. 1. Ballistic Instrument

thread or bundle of threads that is to be broken; the other end of the thread or bundle is secured in a small clamp, known as the "rider," which is not fastened to the pendulum except by means of the thread. The height of swing of the pendulum after a given fall is first noted, and then the height of swing, after the pendulum falls from the same height as before, with the thread (or bundle) in position; the rider, which lies on a ledge on the side of the pendulum, catches on fixed projections (*P*, Fig. 2) and the thread is broken by a longitudinal pull at the lowest part of the swing, the rider being thrown off.

If W = mass of pendulum in grams,
α = angular rise of pendulum when no thread is broken,
β = angular rise of pendulum after breaking thread,
l = length of pendulum between point of suspension and centre of gravity in centimetres,
e = work done in gram-centimetre units,

then
$$e = Wl(\cos\beta - \cos\alpha),$$

on the assumption that no energy is consumed otherwise than in breaking the thread. The rider, however, abstracts energy when it is thrown off, and energy may be lost otherwise, but, although a correction for the energy abstracted by the rider may be introduced if further assumptions are made, the calculation is made by the above formula when the instrument is used for comparing different samples of material under similar conditions.

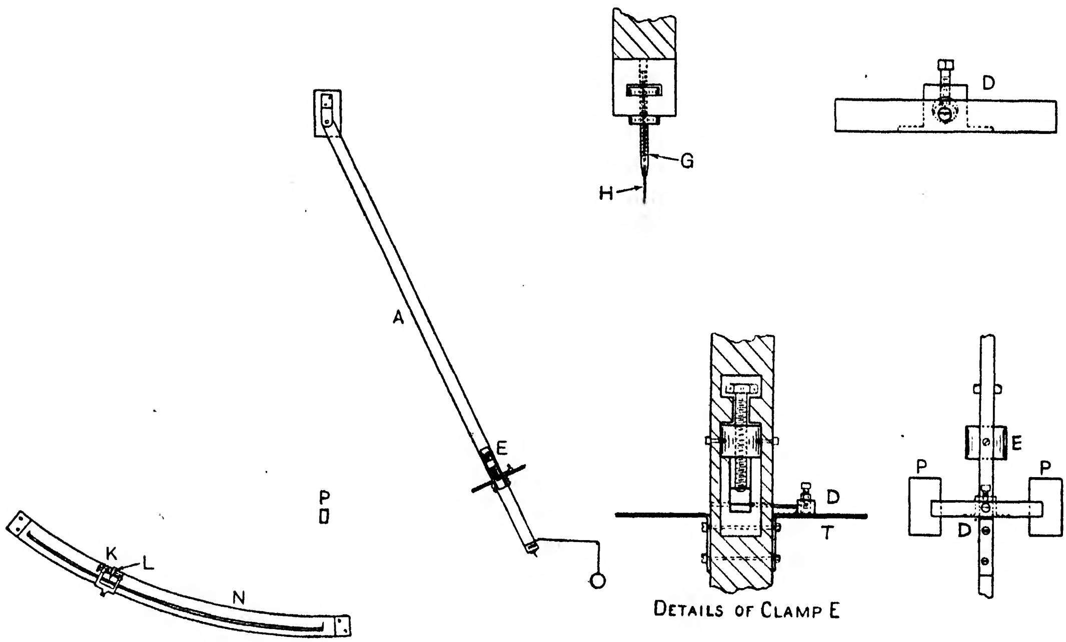


Fig. 2

Frame

The parts of the instrument are attached to the front of a massive frame of cast iron which may either be bolted with its back flat against a wall, or against a cast iron buttress if it is required to stand; levelling screws are provided.

Pendulum

The pendulum consists of a boxwood lath (A, Fig. 2) about a metre long (a metre stick); it is weighted towards its lower end and is suspended at its upper end by means of a steel pivot passing through the lath at right angles to its breadth and provided with conical ends which fit into hardened steel cups set on the frame. A rectangular piece of the boxwood removed at the centre of percussion is replaced by a steel clamp (E, Fig. 2) by which one end of the thread or bundle is secured; the thread passes through a hole in the side of the lath, and its other end is secured to the clamp of the rider as described above.

Rider

Into a piece of boxwood 0·7 cm. × 0·7 cm. × 4·5 cm., a fixed steel base is inserted, against which a movable steel block can be screwed down between guides by a screw which fits into a cup on the upper side of the movable block (D, Fig. 2). With this arrangement, slipping of the thread, which was at first troublesome, is avoided, and the weight of the rider is kept small (about 4·3 grams); but the clamp must be inspected from time to time.

Recording device

At the lower end of the pendulum, inserted along its longitudinal axis, is a brass tube (G, Fig. 2); the tube contains a needle H, which can move freely up and down for a limited distance and which has a stop at its upper end. The brass tube can be screwed up and down and locked in position, so that the needle just touches the smoked glass plate which lies in the carriage K along a chord of the scale; the needle gives a clear trace on the glass plate with negligible friction; its slight upward movement does not appreciably alter the centre of gravity of the pendulum. The carriage K can be moved along the scale N, and can be clamped in any desired position. The limits of the traces on the smoked glass plate are read by a pointer L which has one arm projecting over the glass plate and another arm on the scale, so arranged that a reading of the pointer gives the position of the arm over the carriage. This gives α and β directly in degrees. This scale can be read to an accuracy of 1/100th degree; the angle of swing is about 25°.

Measurements in which the pendulum was set to fall through different angles indicate an increased absorption of energy with increasing velocity of the pendulum at the time of break, the mass of the pendulum and of the rider remaining the same. Comparisons of the amount of energy absorbed, as determined by this pendulum apparatus and as calculated from stress-strain diagrams, appear to show that the work done in breaking a given length of material by a slowly increasing load is about one-half only of the work done in breaking by the pendulum. The length broken has usually been 2 cm. between the clamps, but the instrument can be set to break other lengths.

2. Recording Extensometer

This instrument is an improved form of an instrument designed by Lonsdale and described in the *Journal of the Textile Institute**.

General Description

A horizontal balance beam (Figs. 3 and 4) is set at right angles across a flexible steel blade disposed horizontally with the surface of the blade vertical; the blade fits into a cross slit on the underside of the beam at its middle, and as the ends of the blade are firmly clamped, any movement of the balance beam caused by applying a tension at one end produces opposing torsions of the blade. The movements of the beam caused by tensions applied by means of a thread or filament attached to the end of the beam, and the elongations of the thread or filament produced by the applied tensions, are recorded by the instrument in the form of diagrams from which measurements of the corresponding loads and extensions can be made if the instrument is suitably calibrated.

Although adaptable, by means of obvious modifications such as the substitution of heavier parts, to the study of yarns or the more robust fibres, the instrument as now described was designed for the study of the delicate filaments of silk of diameter about 10 μ;

* 17 (1926), T 248.

a recording system in which a pen is employed was therefore inadmissible owing to the excessive frictional errors at the low degrees of loading concerned, and a photographic method of recording was adopted instead.

Blade

The blade S is 9 cm. long, 0·7 cm. broad and 0·015 cm. thick. It is secured at each end to a brass mount N. A simple screw motion fitted with a locking nut and acting on one of the two clamps holding the blade enables tension to be put on the blade, thus regulating the amount of tilt of the beam for a given load applied to the end of the beam.

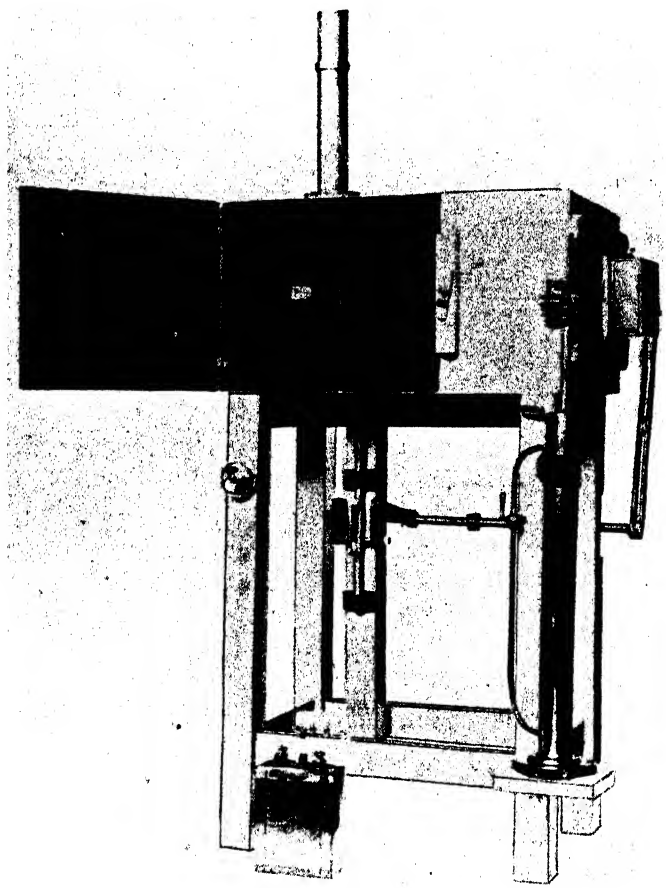


Fig. 3. Recording Extensometer

Beam

The balance beam B is mounted at the middle of the blade; at one end a hook H is hung by means of a "fusee" chain; and the beam also carries the mirror referred to below.

Recording Device

(i) *Load.* A small mirror mounted across the middle of the balance beam at an angle of 45° to the vertical reflects a vertical pencil of light in a horizontal direction on to a photographic film held in a film holder, C; by hanging weights (1 gram, 2 grams, etc.) on the hook H at the end of the beam corresponding vertical deflections of the spot of light on the film

are produced and recorded, thus furnishing the load scale for the curves obtained on this film (see below). For silk filaments the tension of the blade S is adjusted so that the deflection of the spot of light on the film is about 0·5 cm. per gram of load; the deflection is then directly proportional to the load.

(ii) *Extension*. The filament under test is held between the hook H on the balance beam and the clamp K situated vertically below the hook; the clamp K is connected by a system of levers to the film holder C, and this in turn by a chain running over a wheel to a heavy piston contained in a vertical cylinder filled with oil. When the piston is allowed to fall in the cylinder the film holder moves on wheels in grooves parallel to the blade S, and exerts a pull on the filament through the connecting system of levers and the clamp K. The vertical

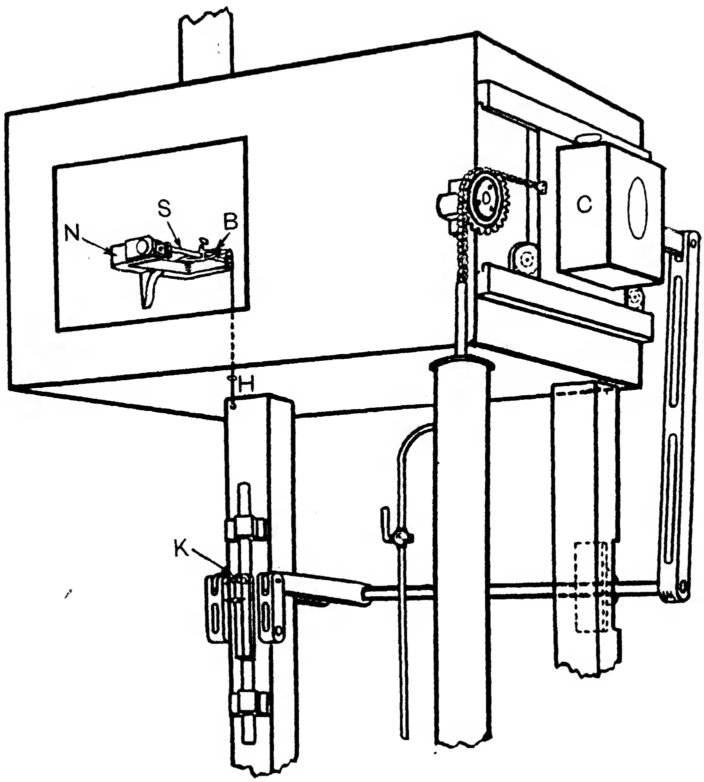


Fig. 4

deflection of the spot of light gives the load as just described under (i) above; at the same time the filament is elongated by an amount equal to the distance through which the clamp K moves, less the displacement of the hook H. The displacement of the clamp K is proportional to that of the film holder C. Thus the spot of light traces a curve on the film of which the ordinates are proportional to the loads on the filament and the abscissae to the elongation of the filament plus the displacement of the hook H. With the system of levers employed the displacement of the film holder C is twice that of the clamp K. The correction c for the displacement of the hook H is small; it is approximately $c = \frac{1}{2}la/b$, where l is the linear dimension of the corresponding load ordinate, a is the perpendicular distance from the axis of the blade to the point of attachment of the fusee chain to the beam B, and b is the distance from the mirror to the film. A traverse of the film holder after breaking the filament produces a reference line of zero load on the film.

Mounting the filament

One end of the filament is attached to a small metal hook by sealing wax or other suitable adhesive, and the other end similarly to a straight wire. The small hook is hung on the hook H of the beam and the wire is gripped by the clamp K. If the use of sealing wax is undesirable, the clamps and methods previously described (Lonsdale, *loc. cit.*) may be used, with, however, an objectionable increase in the inertia of the system.

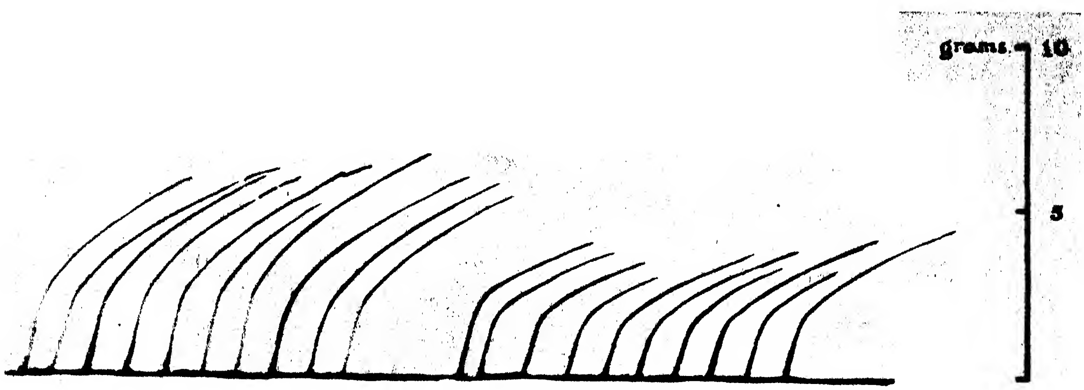


Fig. 5

Records

A roll film is used. By means of a ratchet mechanism in the holder C the film can be wound on for about 0·5 cm. after each curve is obtained; thus 60–100 curves may be obtained on one film. Fig. 5 shows the curves obtained by breaking 20 filaments in succession (two sets of 10; each set made by cutting 100 cm. of filament into 10 cm. lengths).

THE ERRORS ASSOCIATED WITH HIGH RESISTANCES IN ALTERNATING CURRENT MEASUREMENTS. By R. DAVIS, M.Sc. Of The National Physical Laboratory.

(*Continued from p.* 312)

(4) Determination of the Characteristics of a Unit

Butterworth has shown* that an earth capacity in any arm of a bridge can be replaced by two earth impedances acting at the ends of the arm together with an impedance in series with the arm. The equivalent network for a unit is illustrated in the diagram below (Fig. 3).

R is the resistance of the unit and in series with R the inductance L is connected; across the ends of the unit are connected to the shield the two condensers of capacity C_1 and C_2, as illustrated in Fig. 3.

Let V be the voltage applied to the unit, the end A being earthed, and let the voltage on the screen be v/q. A relation between the values of L, C_1 and C_2 and C, where C is the

* *Proc. Phys. Soc.* **34** (1921) 8.

total capacity of the resistance R to the screen, assumed to be uniformly distributed, will be derived.

Let the currents in the network be as indicated in the diagram.

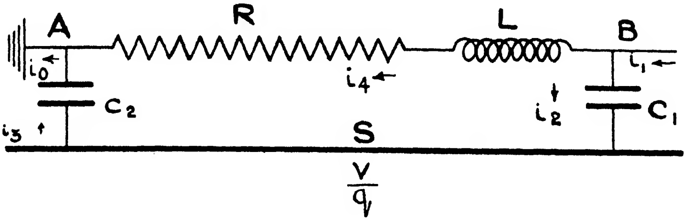


Fig. 3

Then
$$i_1 = i_4 + i_2,$$
$$i_0 = i_4 + i_3,$$
$$i_2 = j\omega C_1 V\left(1 - \frac{1}{q}\right),$$
$$i_3 = \frac{j\omega C_2 V}{q},$$
$$i_4 = \frac{V}{R + j\omega L}.$$

Hence
$$\left.\begin{aligned} i_1 &= \frac{V}{R^2 + \omega^2 L^2}\left[R - j\omega L + j\omega C_1\left(1 - \frac{1}{q}\right)(R^2 + \omega^2 L^2)\right] \\ i_0 &= \frac{V}{R^2 + \omega^2 L^2}\left[R - j\omega L + j\omega C_2 \frac{1}{q}(R^2 + \omega^2 L^2)\right] \end{aligned}\right\} \quad \text{......(11).}$$

Let Ti_0 and Ti_1 represent the time constants of the network in terms of the currents i_0 and i_1 respectively.

Then
$$Ti_0 = -\frac{L}{R} + \frac{C_2}{q}\left(R + \frac{\omega^2 L^2}{R}\right)$$
and
$$Ti_1 = -\frac{L}{R} + C_1\left(1 - \frac{1}{q}\right)\left(R + \frac{\omega^2 L^2}{R}\right);$$
when $q = \infty$
$$Ti_0 = -\frac{L}{R} = -\frac{RC}{6} \quad \text{......(12),}$$
when $q = 2$
$$Ti_0 = -\frac{L}{R} + \frac{C_2}{2}\left(R + \frac{\omega^2 L^2}{R}\right) = +\frac{RC}{12} \quad \text{......(13),}$$
when $q = 1$
$$Ti_0 = -\frac{L}{R} + \frac{C_2}{1}\left(R + \frac{\omega^2 L^2}{R}\right) = +\frac{RC}{3} \quad \text{......(14).}$$

The right-hand side of equations (12), (13) and (14) are derived from equation (5), section 2.

From equations (12) and (13) we obtain
$$\left.\begin{aligned} L &= \frac{CR^2}{6} \\ C_2 &= \frac{C}{2}\,\frac{1}{1 + \dfrac{\omega^2}{R^2}L^2} \end{aligned}\right\} \quad \text{......(15).}$$

Similarly three equations may be derived from the expressions for Ti_1 giving

$$\left.\begin{aligned} L &= \frac{CR^2}{6} \\ C_1 &= \frac{C}{2}\frac{1}{1+\frac{\omega^2L^2}{R^2}} \end{aligned}\right\} \qquad \text{......(16).}$$

From equations (15) and (16) it is seen that if the capacity of the resistance is uniformly distributed to its screen, then the two end capacities C_1 and C_2 are equal.

Hartshorn and Wilmotte have described* a method for determining the characteristics L, C_1 and C_2 for a resistance shielded by earth potential. To determine the phase angle of a unit when shielded at the mean potential of the unit a similar procedure can be adopted. The unit AB constitutes one arm of a bridge for measuring time constants (Fig. 4).

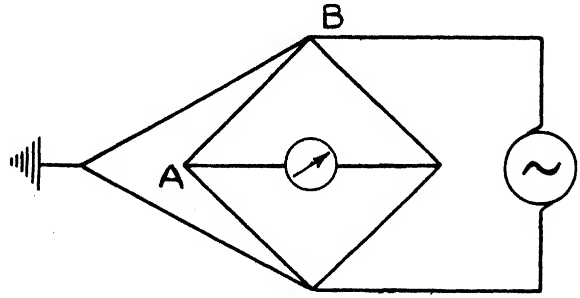


Fig. 4

Case 1. The screen is connected directly to earth and the point A is maintained at earth potential without being connected directly to earth, by means of a Wagner earth. Then the bridge gives a measure of the time constant of the network with respect to the current i_4, *i.e.* of $-L/R$. Let the value of this reading be x.

Then $$-\frac{L}{R} = x = -\frac{RC}{6} + k \qquad \text{......(17),}$$

where C has the significance already given to it and k is the time constant of the winding of the unit due to self inductance and distributed capacity.

Case 2. The screen is connected to A and A is maintained at earth potential by means of a Wagner earth. Then the bridge gives a measure of time constant with respect to the current $i_4 + i_2$, that is i_1. Let the value of this reading be y.

Then $$-\frac{L}{R} + C_1\left(R + \frac{\omega^2L^2}{R}\right) = y = +\frac{RC}{3} + k \qquad \text{......(18).}$$

Case 3. By reversing A and B, connecting the case to B, and maintaining B at earth potential we obtain the relation

$$-\frac{L}{R} + C_2\left(R + \frac{\omega^2L^2}{R}\right) = y' = +\frac{RC}{3} + k \qquad \text{......(19),}$$

where y' is the reading obtained.

If y and y' are not equal then the assumption that the resistance has capacity uniformly distributed to the screen does not hold, and under these circumstances, when the unit is shielded at its mean potential, the current at the high voltage end differs in phase from the current at the low voltage end. The additional phase angle error introduced by such asymmetry is proportional to the number of units used, and also proportional to the difference

* *Journ. Scient. Instr.* 4 (1926) 33.

between C_1 and C_2, *i.e.* the difference between y and y'. By a symmetrical arrangement of the sections of a unit in the container this asymmetry can be avoided and the differences between y and y' made negligible. When this is done then $y = y'$ and $C_1 = C_2$ and equations (18) and (19) become identical.

From equations (17) and (18) $\quad RC = 2\,(y - x),$

$$k = \frac{2x + y}{3},$$

α the phase angle of the unit is equal to

$$\omega\left(\frac{RC}{12} + k\right) = \omega\left(\frac{y - x}{6} + \frac{2x + y}{3}\right) = \frac{(x + y)\,\omega}{2}.$$

Adjustment of Phase Angle.

From the measurements of x and y the values of RC and k can be determined. When the shield is maintained at the mean potential of the unit the phase angle of the unit at both the low and the high voltage ends of the unit is $\omega\left[\frac{RC}{12} + k\right]$.

The time constant k can be either positive (leading) or negative (lagging). If k be negative and equal in value to $RC/12$ the phase angle of the unit is zero. In general when the resistance of the unit is high—greater than 10,000 ohms—the effects of distributed capacity predominate and k is generally positive. Then k equals RC' approximately where R is the resistance of the unit and C' is a capacity connected across the unit. By inserting an inductance in series with the resistance of value $L = R^2\left(\frac{C}{12} + C'\right)$ the positive time constant is balanced by an equal negative time constant, and in terms of the current at the two ends of the unit the phase angle is zero. In practice the value of L is only given approximately by the expression above as the insertion of the inductance increases the value of C. By trial and error the correct value of L to obtain compensation, within the limits of reading of the bridge, can rapidly be obtained.

Experimental Results Obtained on Unit.

A unit was made up consisting of ten sections, each section being 15,000 ohms. The wire used was single silk covered Eureka 0·004 in. in diameter and it was wound on cards 29 cm. long, 8 cm. wide and 0·3 cm. thick. The ten sections were spaced symmetrically, 4 cm. apart, in a rectangular metal container 54 cm. by 34 cm. by 15½ cm. The tests were carried out using a bridge, the time constants of the other three arms of which were known.

Some preliminary experiments showed that the time constant k was positive.

An inductance having a value of 0·188 henry and of negligible resistance compared with 150,000 ohms was inserted in the middle of the winding, and measurements of x and y were made, (1) with the inductance short-circuited, and (2) with the inductance inserted in the winding.

(1) *Inductance Short-Circuited.*

$$x = -\,24_{20}\,.\,10^{-9},$$

$$y = +\,55_{00}\,.\,10^{-9},$$

$$\therefore\; RC = 2\,(y - x) = 2\,(55_{00} + 24_{20})\,10^{-9}$$

$$= +\,15_{840}\,.\,10^{-9},$$

$$\frac{RC}{12} = +\,13_{20}\,.\,10^{-9},$$

$$k = \frac{2x + y}{3} = \frac{-\,48_{40}\,.\,10^{-9} + 55_{00}\,.\,10^{-9}}{3}$$

$$= +\,22_{0}\,.\,10^{-9}.$$

Therefore the value of the unbalanced time constant $= +\ 15_{40} \cdot 10^{-9}$, which gives a phase angle at 50 cycles per second of $+\ 4{\cdot}8_5 \cdot 10^{-4}$ (leading). This result is also obtained directly from the expression $\omega \dfrac{(x+y)}{2}$.

(2) *Inductance of* 0·188 *henry in Circuit.*

$$x = -\ 36_{50} \cdot 10^{-9},$$
$$y = +\ 42_{70} \cdot 10^{-9}.$$

The value of the unbalanced time constant equals $\frac{1}{2}(x+y)$

$$= \frac{(-\ 36_{50} + 42_{70})}{2} \cdot 10^{-9}$$
$$= +\frac{6_{20}}{2} \cdot 10^{-9}$$
$$= +\ 3_{10} \cdot 10^{-9}.$$

Therefore the phase angle of the unit at a frequency of 50 cycles per second under the specified conditions equals $+\ 0{\cdot}9_5 \cdot 10^{-4}$ (leading).

The change in the time constant due to the insertion of the inductance equals

$$(15_{40} - 3_{10}) \cdot 10^{-9} = 12_{30} \cdot 10^{-9}.$$

This is equivalent to the insertion in series with the 150,000 ohms of an inductance equal in value to

$$150{,}000 \times 1230 \cdot 10^{-9} = 0{\cdot}18_5 \text{ henry}.$$

The actual value of the inductance used was 0·188 henry.

Accuracy of Experimental Results.

The sensitivity of the bridge was such that the values of x and y could be determined to an accuracy of 20 parts in 10^{-9}. The unbalanced time constant is obtained by taking half the difference between two readings, each of which can be in error by 20 parts in 10^{-9}. Therefore the value of the unbalanced time constant may be in error by $20 \cdot 10^{-9}$. The difference between the two unbalanced time constants of test (1) and test (2) may therefore be in error by $40 \cdot 10^{-9}$, giving a possible error in the calculated value of the inductance necessary to produce this change of time constant of $40 \cdot 10^{-9} \times 150{,}000$, which is equal to $0{\cdot}006\,H$.

The actual discrepancy between the calculated and the actual value of the inductance is $0{\cdot}003\,H$.

From the value of the expression $(y - x)$ which gives a measure of the capacity of the winding of the unit to its screen, it will be seen that C is the same in both cases. This illustrates the advantage of carrying out the first test with the inductance short-circuited in the winding. The additional complication of an increase in the value of C due to the introduction of the inductance is avoided.

The second test showed that the value of the unbalanced time constant was $310 \cdot 10^{-9}$, so that the additional inductance required in order that the unit should have zero phase angle when shielded at its mean potential would be $(310 \cdot 10^{-9} \times 150{,}000)\,H = 0{\cdot}046\,H$.

(5) Practical Considerations in the Designing of a Resistor for High Voltages, having a small Phase Angle at the Low and High Voltage Ends

From the preceding paragraphs it will be seen that two important considerations in the design of a high voltage resistor having a small phase angle at the low and high voltage ends, are:

(1) The design of the individual unit.

(2) The correct adjustment of the shield potentials.

(1) It is essential that the condition of uniform distribution of the capacity of the windings to the shield shall hold as closely as possible. In order to obtain this, the resistance cards which comprise the unit must all be similar, and their arrangement in the container which comprises the shield must be symmetrical. Some experiments may be necessary to obtain the condition where C_1 and C_2 are nearest to being equal.

(2) In practice, the shield potentials will be obtained by means of an auxiliary resistance connected in parallel with the shielded resistor. This resistance will be of the same order of magnitude as the shielded resistance, and consequently it will have a large capacity to earth. For example, if a shielded resistor for 100 kilovolts is required, the auxiliary resistance might have a value of 2 megohms. In the case of a resistor referred to earlier in this paper, the estimated value for the capacity to earth for a section of 600,000 ohms was 300 micromicrofarads. If the design of the auxiliary resistor were similar to this, then on the assumption that the earth capacity is proportional to the resistance, its earth capacity would be 1000 micromicrofarads. It is important that some estimate should be formed of the effect of this earth capacity on the current in the auxiliary resistance, as the screen potentials along the shielded resistor are closely related to this current.

It has been shown that the current i_0 at the earthed end of a resistor R, having a uniformly distributed capacity C to earth, is

$$i_0 = \frac{V}{R\left(1 + \frac{a^2}{6} + \frac{a^4}{120}\right)},$$

where V is the applied voltage, $a^2 = jRC\omega$,

$$i_0 = \frac{V}{R}\left[1 + \left(\frac{a^2}{6} + \frac{a^4}{120}\right)\right]^{-1},$$

$$= \frac{V}{R}\left[1 - \frac{a^2}{6} + \frac{7a^4}{360}\right],$$

neglecting higher terms,

$$= \frac{V}{R}\left(1 - \frac{jRC\omega}{6} - \frac{7}{360} R^2C^2\omega^2\right).$$

The magnitude of this current, combining the real and imaginary parts, is

$$\frac{V}{R}\left[1 - \frac{14}{360} R^2C^2\omega^2 + \frac{R^2C^2\omega^2}{36}\right]^{\frac{1}{2}},$$

$$= \frac{V}{R}\left[1 - \frac{1}{180} R^2C^2\omega^2\right] \qquad \text{......(15).}$$

The current at the high voltage end

$$i_1 = \frac{V}{R}\frac{\left[1 + \frac{a^2}{2} + \frac{a^4}{24}\right]}{\left[1 + \frac{a^2}{6} + \frac{a^4}{120}\right]}, \quad = \frac{V}{R}\left(1 + \frac{a^2}{2} + \frac{a^4}{24}\right)\left(1 - \frac{a^2}{6} + \frac{7a^4}{360}\right),$$

$$= \frac{V}{R}\left[1 + \frac{a^2}{3} - \frac{a^4}{45}\right],$$

neglecting higher terms,

$$= \frac{V}{R}\left(1 + \frac{jRC\omega}{3} + \frac{1}{45} R^2C^2\omega^2\right).$$

The magnitude of this current combining the real and imaginary parts is

$$\frac{V}{R}\left[1+\frac{R^2C^2\omega^2}{9}+\frac{2}{45}R^2C^2\omega^2\right]^{\frac{1}{2}},$$

$$=\frac{V}{R}\left[1+\frac{7}{45}R^2C^2\omega^2\right]^{\frac{1}{2}},$$

$$=\frac{V}{R}\left[1+\frac{7}{90}R^2C^2\omega^2\right]. \qquad \text{......(16).}$$

When $R = 2 \times 10^6$ ohms.

$C = 10^{-9}$ farads.

$\omega = 3{\cdot}14 \,.\, 10^2.$

The current

$$i_0=\frac{V}{R}\left[1-\frac{1\times 4\,.\,10^{12}\times 10^5}{180\times 10\,.\,18}\right],$$

$$=\frac{V}{R}\left[1-\frac{2{\cdot}2}{10^3}\right].$$

This result shows that the current at the low voltage end of the auxiliary resistance is about two parts in a thousand lower than it would be if there were no error due to earth capacity.

The current

$$i_1=\frac{V}{R}\left[1+\frac{31}{10^3}\right].$$

This result shows that the current at the high voltage end of the auxiliary resistance is about thirty-one parts in a thousand higher than it would be if there were no error due to earth capacity.

From these results it will be seen that if the shield potential at the low voltage end of the shielded resistor is correctly adjusted, then the shield potential at the high voltage end will be 3·3 per cent. high. The error introduced by this steadily increasing incorrect adjustment of the shield potentials is approximately the same as if all the shield potentials had been adjusted to too high a value by about $3{\cdot}3/2 = 1{\cdot}7$ per cent.

From equations (9) and (10) the increase in the phase angles ϕ_1 and ϕ_2 due to this effect can be determined.

Consider a shielded resistor consisting of 100 units, each unit being designed for 1000 volts.

The value of $RC\omega$ for the unit might equal 0·0006 (section II).

From equation (9), when $n = 0$,

$$\phi_1=\frac{RC\omega}{12}=0{\cdot}0000_5,$$

when $n = 1{\cdot}7$,

$$\phi_1=\frac{RC\omega}{1200}(100+3\times 1{\cdot}7\times 100)=RC\omega\frac{610}{1200}=0{\cdot}0003 \text{ approximately.}$$

In this example the effect of the earth capacity of the auxiliary resistance had been to increase the phase angle at the low voltage end of the shielded resistor six times. Thus it will be seen that if the error introduced by the earth capacity associated with the auxiliary resistance is not compensated for in some way, a practical limit is placed on the size of a shielded resistor, which is required to have only a small phase angle. The shielding of the auxiliary resistance itself has been suggested. When this is done the analysis which has been already detailed will then apply to the auxiliary resistance, and it will be seen that the current in the auxiliary resistance will be practically constant, and consequently the shield potentials of the main resistor will be accurately adjusted to their appropriate values.

To obtain the appropriate screen potentials for the auxiliary resistance, either (*a*) a third auxiliary resistance would be needed, connected in parallel with the other two, or (*b*) if the supply transformer were of suitable design, these potentials could be obtained directly from suitable tappings on the transformer. Dr E. H. Rayner, of the National Physical Laboratory, has suggested the use of tappings from a suitable transformer for providing the potentials of the shields of the auxiliary resistance.

(*Concluded*)

NEW INSTRUMENTS

A TUNING-FORK CONTROLLED AUDIO-OSCILLATOR

By CLAUDE L. LYONS, Member I.R.E.

THE need is frequently felt in research laboratories devoted to electrical engineering, radio engineering or communications, chiefly in connection with bridge measurement work, for a thoroughly dependable, cheap and compact source of alternating current of low power having reasonably satisfactory wave-form. The frequency of such a device must remain constant even on lengthy "runs".

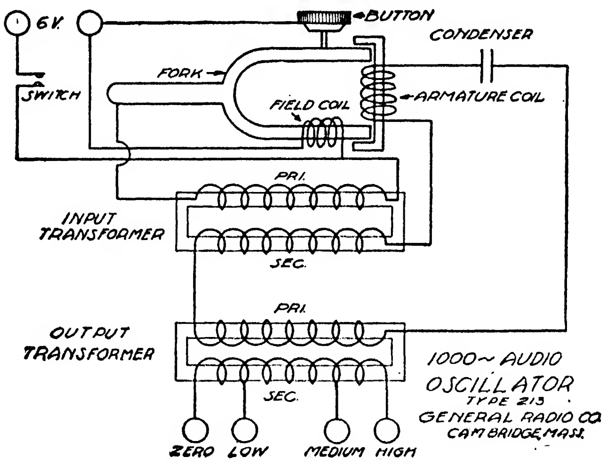


Fig. 1. Schematic Circuit.

In a recent paper in this *Journal**, the author briefly referred to a small fork-controlled audio-oscillator, the type 213 audio-oscillator of the General Radio Company, of Cambridge, Mass., U.S.A. As this has been found to be of exceptional dependability and utility it is thought that a brief description of it may be of interest to readers of the *Journal*. No other oscillator of small power (and many have been tried from time to time) has been found as satisfactory, or able to withstand the mis-use which all such instruments occasionally have to suffer.

Fig. 1 gives the schematic circuit and Fig. 2 shows a view of the interior of the instrument. The output of the oscillator is approximately 60 milliwatts (0·06 watt), at 1000 ~. By use of a tapped secondary output transformer, three different voltages may be obtained, as follows:

Point	*Voltage*	*Current*
Low	0·5 volts	100 milliamperes
Medium	1·5 volts	40 milliamperes
High	5·0 volts	12 milliamperes

* 5 (1928) 155.

However, for some capacity measurements it is desirable to use a higher voltage. Such increased voltage may be obtained by connecting an inductance and a capacity in series across the high voltage output terminals of the oscillator. By adjusting this circuit to resonance, voltages as high as 50 or 100 may be obtained by connecting output leads across the condenser. The instrument operates satisfactorily on from 4 to 8 volts, and draws approximately 0·13 ampere; when running it may be heard directly through the air for a distance of about 25 feet. If this is undesirable it must be "muffled" by enclosure in a sound-proof box, or by operation in another room, taking the output to the test bench by a pair of twisted flexes.

The action, which may be readily followed from Fig. 1, will be seen to be similar to that of a vacuum-tube oscillator. On closing the switch the fork becomes magnetized by the current flowing through the field coil, which is wound over one prong of the fork, and the prongs are drawn away from their position of rest. This initial movement of the prongs disturbs the microphone button, and the resistance through the carbon granules is thereby changed. In this manner the resistance of the circuit is varied, causing a variation in the

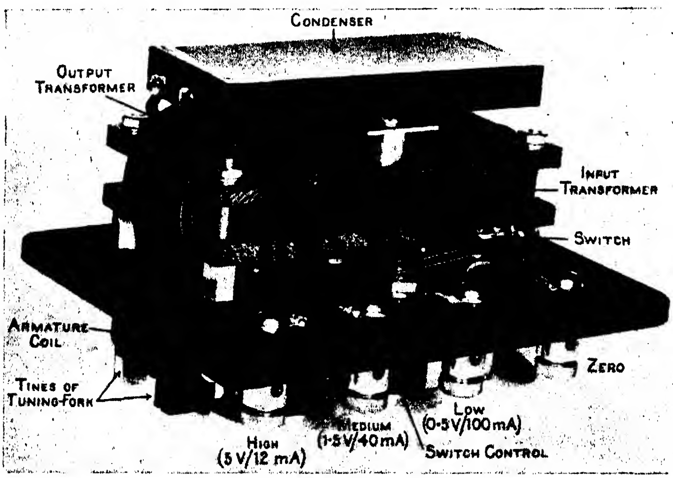


Fig. 2. Internal appearance of G.R. Type 213 Audio-Oscillator.

current flowing. The motion of the prongs is most rapid at the instant they are passing through their normal position of rest, and, therefore, the variation in the microphone resistance is also most rapid at this instant; the alternating E.M.F. is consequently at a maximum for this condition. The primary of the input transformer, which is in the circuit, is highly inductive; hence, the current lags 90° behind the E.M.F. The alternating E.M.F. induced in the secondary of the input transformer also lags 90° behind the inducing current. However, since the circuit in which the secondary is included is tuned to resonance, the current in this circuit will be in phase with the induced E.M.F. The current is therefore either 180° out of phase, or in phase, with the motion of the fork. Its effect on the armature coil, however, is made to be in phase with the fork by connecting the coil in the proper sense, so that the magnetic effect of the current through the armature coil assists the motion of the fork, thereby increasing its amplitude. The amplitude rapidly reaches a steady value and the fork then continues to vibrate with this constant amplitude as long as the switch remains closed. The operation is disturbed, however, if the oscillator is overloaded.

Features worthy of note are the design of the microphone button, and the use of two transformers. To effect permanency and ensure that the former will be insensitive to mechanical shocks, and yet operate properly at 1000 ~, use is made of its high inertia at that

frequency. One side of the button is attached to the tuning-fork by means of a flat, short spring. The other side, which has a projecting terminal, is held in position by a specially designed self-centring spring. Such care is essential when it is remembered that a displacement as small as 1/500″ from the normal position of the mica would destroy the perfect operation of the button. The adjustment of the button is permanent and it needs no attention after leaving the maker's laboratory. The employment of two transformers prevents the output from containing any direct current component. Each transformer has a slight air-gap to prevent distortion of the wave-form. Since, however, the magnetic circuits are all nearly closed iron paths, there is very little outside field, a feature of considerable importance in bridge measurements.

The oscillator is not intended to displace the larger types designed to furnish outputs of several watts, being intended primarily for general laboratory use where power of really good wave-form is required for a single bridge; and if the pureness of the wave-form obtainable is to be retained, it is essential that the instrument should not be overloaded. The instrument is extremely light, of small dimensions, $6'' \times 5'' \times 4\frac{3}{4}''$, and of very reasonable cost.

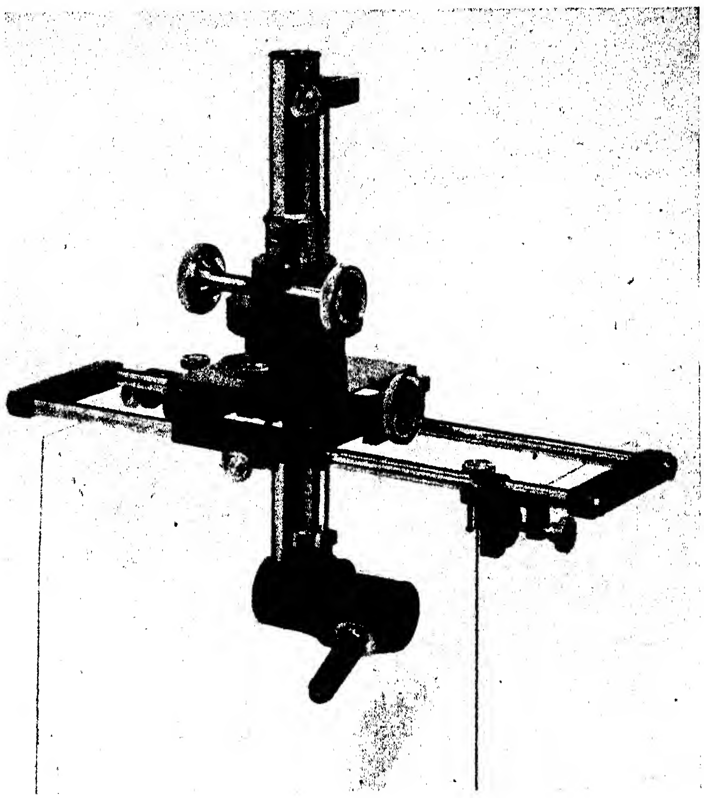
A NEW AQUARIUM MICROSCOPE

A NOVEL form of tank or aquarium microscope has recently been devised by Mr D. J. Scourfield and made by Messrs Ogilvy & Co., 20 Mortimer Street, London, W1. It is described in detail in the *Journal of the Royal Microscopical Society* (June, 1928, pp. 129–132, 1 Plate). Unlike the usual type of such microscopes, whether simple or compound, it is designed to work *inside* instead of outside the aquarium, the lower end of the body-tube and the objective being immersed in the water.

The instrument consists essentially of a long body-tube (10 inches, or more if required) which can be pushed up and down by hand in a sleeve rotating in what is practically a mechanical stage with horizontal rectangular rack and pinion movements, the rotating sleeve itself being provided with the usual vertical rack and pinion focusing arrangement. The mechanical stage is carried on a saddle which slides freely on two stout parallel rods held together by cross-bars at their ends, thus forming a "bridge" which can be placed in any position across the top of the aquarium. The characteristic feature of the instrument is, however, the arrangement by which the objective can be rotated in a vertical plane, as this movement, combined with the horizontal rotation of the body-tube and the rectangular movements already mentioned, allows of the objective being brought to bear upon any part of the interior of the aquarium at any desired angle. The arrangement referred to is described as follows: "At the lower end of the body-tube, and with its axis at right angles to it, is fixed a cylindrical casing containing a right-angled prism. In line with this, and therefore standing out at right angles to the tube of the microscope, is attached a second cylindrical casing also containing a right-angled prism. This second casing acts as the objective carrier, the objective being screwed on at right angles to the axis of the casing. The second casing is capable of complete rotation upon the first in a vertical plane, the junction between the two being made by a water-tight fitting. Rotation is effected by toothed gearing worked by a stainless steel rod from a milled head placed near the eye-piece." The body-tube is chromium plated and the casings coated with cellulose enamel in order to resist the action of the water whether fresh or salt. The objectives for use with this instrument should normally be water-immersions, but it has been found that for low power work ordinary dry objectives are reasonably good. There appears to be no theoretical limit to the objectives which may be used, but the question of illumination becomes increasingly difficult as

medium and higher powers are employed. To prevent leakage of water into the microscope a little vaseline or similar material is necessary on the screw thread and flange of the objective and sometimes also on joints in the objective mount.

This microscope has been designed to enable observations to be made on small aquatic organisms under conditions as nearly approaching their natural surroundings as possible.



It is anticipated that it may be found particularly useful in connection with organisms making use of the surface-film, as by its means they can be viewed both from below and from the side as well as from above if required. It is suggested that this type of microscope might also prove convenient for use out of water, for the examination of pipes and hollow parts of machinery not easily accessible in the ordinary way.

LABORATORY AND WORKSHOP NOTE

A METHOD OF MAINTAINING CONSTANT HUMIDITY IN CLOSED CHAMBERS. By R. H. STOUGHTON, B.Sc., A.R.C.S.

Department of Mycology, Rothamsted Experimental Station, Harpenden, Herts.

In connection with some experiments on the influence of environment on the development of angular leaf spot disease of cotton it was necessary to devise some simple means of maintaining a constant humidity in a small closed chamber. In the first apparatus designed (see *Ann. App. Biol.* xv, 3, 1928) the humidity was controlled by passing a stream of air into the chamber through a glass vessel containing water, the temperature of which was controlled

by a carbon filament electric light bulb operated through a relay by a hygrostat within the chamber. By this means the humidity could be controlled within a four or five per cent. range. Further experiments have led to the production of a modification of this apparatus which has been found to be more satisfactory in practice and to give a closer control.

In place of the glass vessel is a tin some eight inches in height and four inches diameter. Through a hole in the bottom of this passes the metal neck of a 16 c.p. carbon filament lamp, a piece of wide rubber tubing serving as a washer. The bulb of the lamp is closely covered with a piece of muslin, stitched in place, the end of which passes through another hole in the bottom of the tin and dips into a vessel of distilled water. A length of lamp-wick stitched to the muslin on the side opposite to the "gathering" of the material and brought

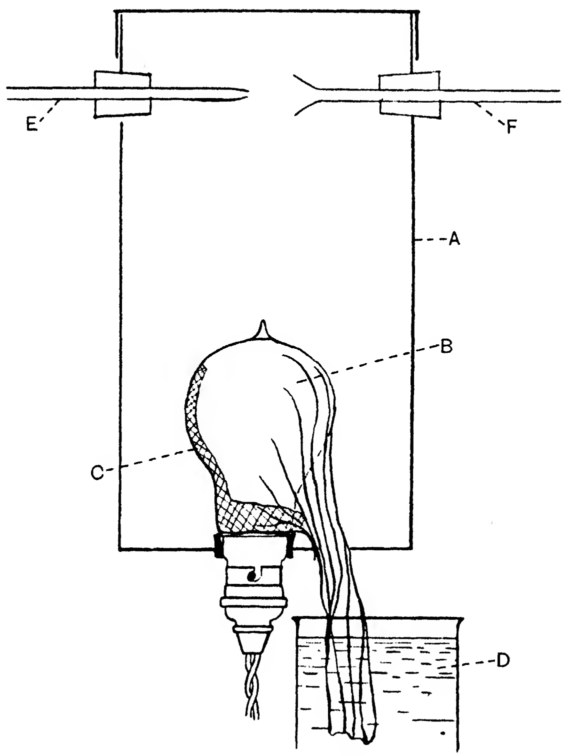


Fig. 1. A. Tin. B. Carbon filament lamp covered with muslin. C. Lampwick stitched to muslin. D. Vessel of distilled water. E. Inlet tube. F. Outlet to chamber.

down through the same hole ensures that the muslin shall be evenly and thoroughly moist. Near the top of the tin are bored two holes diametrically opposite, each having a rubber stopper through which passes a short length of glass tubing. The tube to serve as inlet is drawn out into a wide "jet" and the outlet to the chamber is made somewhat funnel-shaped. The "jet" of the inlet is usually placed about an inch from the funnel of the outlet. The arrangement will be clear from the figure (see Fig. 1). The carbon filament lamp is controlled as previously described through a relay operated by a hair-hygrostat of any type and provided with electric contacts, within the chamber. A fairly strong stream of air (4–5 cubic feet per hour) is blown through the apparatus by a water- or electric blower.

When the lamp in the tin is not glowing, the air-stream from the "jet" passes straight through the outlet without taking up any appreciable amount of moisture in its passage through the tin, and this entry of air, which is usually drier than that in the chamber, results in a drop in humidity within the latter. At the required point the hygrostat operates the

relay, switching on the current to the lamp. The tin rapidly becomes filled with steam and some of this is carried into the chamber by the stream of air until the breaking of the hygrostat contacts again switches off the lamp.

The advantage of this apparatus over the previous type is the rapid heating and cooling of the lamp, resulting in a far shorter lag on either side of the required point. For low humidities it is necessary to dry the air before passing it through the apparatus either by means of calcium chloride or by freezing. Fine control of the range of variation can be obtained by adjusting the distance between the inlet and outlet tubes within the tin. If they are placed wide apart the air-stream will take up some water-vapour on its passage through the tin, even when the lamp is off, while when close together little or none is carried through except when the lamp is glowing.

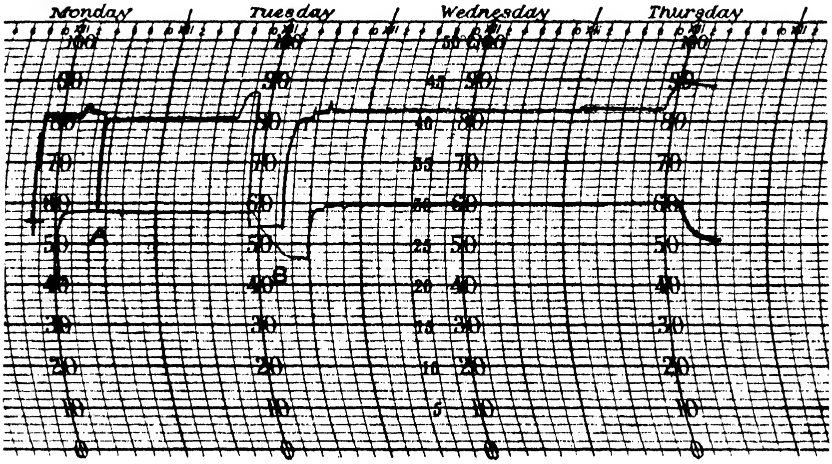


Fig. 2. Upper curve Humidity. Lower curve Temperature. (Note that there is a difference of three hours between the records.)
Point A. Door of chamber opened for a few minutes.
Point B. Chamber opened for four hours and then apparatus restarted.

The chart reproduced (Fig. 2) shows a record obtained from an apparatus of this type applied to a chamber $4' \times 3' \times 2'$ containing growing plants. The air temperature was maintained constant by a thermostat. The first fall in the humidity record (point *A*) indicates a point where the chamber was opened for a minute or two and illustrates the rapidity with which the required humidity was recovered. The second break (*B*) is at a point where the chamber was left open for a few hours and then set to run at a higher temperature. The hygrostat employed was one manufactured by Messrs Negretti and Zambra.

CORRESPONDENCE

THE THOMAS RECORDING GAS CALORIMETER

On page 303 of the September number of the *Journal of Scientific Instruments* a review is published of the brochure (Fuel Research Technical Paper, No. 20) issued by the Department of Scientific and Industrial Research describing an investigation made at H.M. Fuel Research Station into the performance of the Thomas Recording Gas Calorimeter. In the

Thomas Calorimeter the heat developed by the combustion of the gas under test is used to heat a stream of air whose rise in temperature is a measure of the calorific value. The proportions of gas and air burnt and of air heated are strictly controlled.

Your reviewer, in mentioning the fact that air and not water is used as the cooling medium, states as follows: "It is difficult to see what advantages are gained by using air as the cooling medium instead of water." We venture to think that he can have given little thought to the subject of recording gas calorimetry, or particularly to the subject of this review, or he would have realized the large group of errors that are automatically eliminated by the employment of air instead of water as the cooling medium. The gas and air burnt and the air heated are all automatically reduced to the same initial temperature and barometric pressure, so that any changes in the density of the gas due to these factors affect equally the density of the air heated, and hence the two media are used under identically similar conditions. Anyone who knows the difficulty of eliminating these errors in water-flow instruments will appreciate what this means.

It may, perhaps, interest some of your readers to know that the late Sir Horace Darwin gave a great deal of thought to the subject of a recording calorimeter, and decided that the theoretically correct method was to heat air and not water. It was not until a patent had been applied for that he learnt (from a source independent of the Patent Office) that the Cutler Hammer Co. of Milwaukee had placed the Thomas Calorimeter on the market. About five hundred of these instruments have been made and sold by the Cutler Hammer Co. in the United States. Since the paper was published by the Department of Scientific and Industrial Research, the Thomas Calorimeter has been approved by the Gas Referees.

It will, we believe, be considered an achievement by those who have had experience of recording calorimeters, that the instrument has recently run for three months without any adjustment whatever, and is recording to within one B.T.U. what is believed to be the correct calorific value of the gas.

For Cambridge Instrument Company, Ltd.

ROBERT S. WHIPPLE.
Joint Managing Director.

45, GROSVENOR PLACE, S.W. 1.
1st October, 1928.

THE OPTICAL SOCIETY

At the meeting of the Optical Society on October 11th, a paper by Colonel J. W. Gifford, F.R.A.S., on "Lenses and Equipment for Ultra-Violet Photography," was read by Professor Pollard, of which the following is an abstract:

A description is given of the type of photographic doublet generally known as rapid rectilinear, in which (1) fluorite and quartz, (2) quartz and calcite are substituted for the ordinary crown and flint glasses. These doublets are therefore more or less transparent to the ultra-violet as well as to the visual spectrum. Corresponding lists of focal lengths for twenty-one wave-lengths are given, as well as the radii, thicknesses, etc., for construction. A cement transparent to the ultra-violet for use with these lenses is described and photographs of the spectra transmitted by certain light filters are given.

A short note, "Some Remarks on Old English Objectives," by H. Boegehold, Ph.D., was communicated by Mr T. Smith; and an historical paper of great interest, on the Development of Spectacles in London from the End of the Seventeenth Century, by Thomas H. Court and Professor Moritz von Rohr, Ph.D., was read by Mr D. Baxandall.

This, the first of a series of papers to be given on the Court Collection, was illustrated at the meeting by examples from the collection shown by Mr Court himself.

Mr Z. A. Merfield of Melbourne University, Australia, gave a brief description and demonstration of reflecting gratings constructed by him which are designed to throw the greater part of the incident light into a single spectrum.

NINETEENTH ANNUAL EXHIBITION OF THE PHYSICAL AND OPTICAL SOCIETIES

The Nineteenth Annual Exhibition of Electrical, Optical and other Physical Apparatus is to be held by the Physical Society and the Optical Society on 8th, 9th and 10th January, 1929, at the Imperial College of Science and Technology, South Kensington.

As on previous occasions the Exhibition will be divided into a Trade Section, comprising the exhibits of manufacturing firms, and a Research and Experimental Section. The preliminary invitation to trade exhibitors has already been issued, and the Exhibition Committee has invited, from Research Laboratories and Institutions and from individual research workers, exhibits suitable for inclusion in the Research and Experimental Section. These will be arranged in three groups:

a. Exhibits illustrating the results of recent physical research.
b. Lecture experiments in physics.
c. Historical exhibits in physics.

Enquires regarding the Exhibition should be addressed to the Secretary, Physical and Optical Societies, 1, Lowther Gardens, Exhibition Road, London, S.W. 7.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Under the Order in Council dated 6th February, 1928, the Lord President of the Council has appointed Sir David Milne-Watson, LL.D., D.L., and Mr Robert Whyte Reid, C.B.E., M.I.M.E., to be members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research, in the place of members who have retired on the completion of their terms of office.

The Lord President has also reappointed Sir James Hopwood Jeans, D.Sc., LL.D., Sec.R.S., to be a member of the Advisory Council for a further period of one year.

CATALOGUES

The September 1928 issue of *Watson's Microscope Record* (W. Watson & Sons, Ltd., 313, High Holborn, London, W.C. 1) contains a number of articles of interest to amateur and other microscopists, and gives particulars and prices of some of the firm's instruments, including the Circuit Stage Van Heurck, and their Binocular and "Service" microscopes. Messrs Watson send also a new price list (October 1928) of second-hand microscopes and accessories.

Messrs Claude Lyons, Ltd., 76, Oldhall Street, Liverpool, send a pamphlet describing a variable resistance for radio work, the "Clarostat," in which adjustment over a wide range is obtained by variation of the pressure of a plunger upon the resistant material, a mixture of pulverized graphite and mica. The standard 20 watt Clarostat is stated to have a range of 100 ohms to 5 megohms. The instrument is supplied also in other forms of varying range and capacity.

Venner Time Switches, Ltd., 45, Horseferry Road, London, S.W. 1, have issued, and will supply on request, a set of Index Cards for use in the catalogue binder, to enable the different models of their Time Switches and other apparatus to be more readily referred to in their general Catalogue.

JOURNAL OF SCIENTIFIC INSTRUMENTS

VOL. V DECEMBER, 1928 No. 12

A QUICK AND SENSITIVE METHOD OF MEASURING CONDENSER LOSSES AT RADIO FREQUENCIES.

BY RAYMOND M. WILMOTTE, B.A., A.M.I.E.E. (From the National Physical Laboratory.)

[*MS. received, 26th June*, 1928.]

ABSTRACT. The method is essentially a substitution method in which an air condenser is substituted for the condenser being measured, the current being brought to the same value in the two cases by inserting a resistance in series. The success of the method largely depends on the construction of a suitable continuously variable resistance, of which a description is given. With careful use the method will give the value of the difference of the equivalent series resistance between the standard condenser and that under test to within 0·01 ohm, or even less when the circuit conditions are very good.

A number of results of condenser measurements are given, and it is shown that the effective series resistance R of the variable air condensers measured can, within the limits of experimental error, be represented by the equation

$$R = r + \frac{1}{aC^2 f},$$

where f is the frequency, C the capacity, and r and a are constants of the condenser. r appears to be the resistance due to bad contacts and leads inside the condenser. Results tend to show that with aluminium plates the constant r is liable to be unexpectedly large, although in many cases it is very small. Also with ebonite the value of a appears to decrease with humidity.

The advantages claimed for the method are its rapidity, facility of working, possibility of working down to a wave-length of at least 50 metres, its comparatively high sensitivity, and most important, its freedom from errors due to reaction back on to the source.

1. METHOD OF MEASUREMENT

THE measurement is made by a substitution method, the condenser under test being replaced by an air condenser (assumed to be perfect) and a series resistance.

The circuit is shown diagrammatically in Fig. 1 and a photograph of the arrangement of the apparatus is given in Fig. 2. The high frequency E.M.F. is induced from a valve oscillator into some convenient coil L. Actually L consists of two coils in series, which can be adjusted relatively to each other to give a variable inductance. This coil is connected to a reversing switch Q. The leads A and B are screened, B being a tube completely surrounding the wire A. The current is measured by a thermo-junction T and galvanometer G. S is a mercury switch by which the current can be rapidly switched from one condenser C_1 and resistance R_1 to the other condenser C_2 and resistance R_2. The screens of the condensers are connected as shown.

The procedure is as follows. Suppose C_1 is to be compared with the standard variable condenser C_2. The switch S is put so that 1 is connected to 2, and the circuit is tuned, first roughly by altering the inductance L and finally by means of the small condenser C_0

fitted with a Vernier drive. (This latter condenser need not be good as regards power factor, since it remains always in the circuit.) The current is then switched over to the standard condenser C_2 and the new circuit tuned by varying C_2. The resistances R_1 and R_2 are now adjusted until the same deflection of the galvanometer is obtained for both positions of the switch S.

If the circuits were absolutely identical in every respect and the condenser C_2 had no loss, the capacity of C_1 would be equivalent to a capacity C_2 and a series resistance $R_2 - R_1$. In order to eliminate small differences that may exist due to E.M.F.'s (either by induction or capacity effects) from the source or the coil L into the parts of the circuit between the

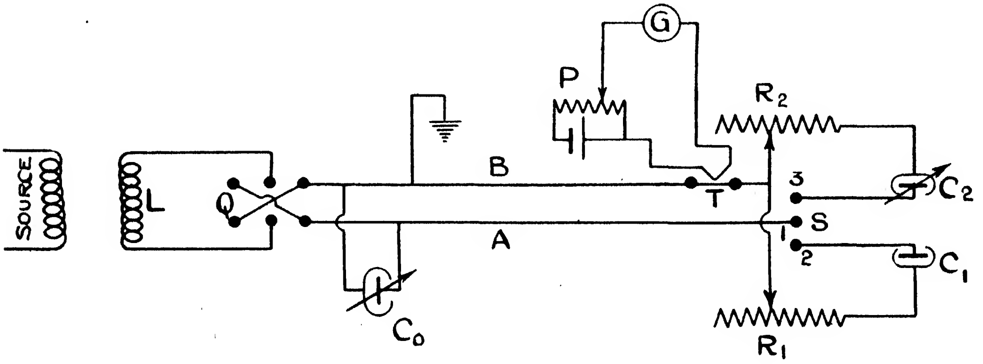


Fig. 1

Fig. 2

condensers and the thermo-junction T, the switch Q is reversed and the readings repeated. It will be found that the tuning is altered, but readjustment on condenser C_0 only is sufficient for both circuits. Generally a small change in the value of $R_2 - R_1$ will be noticed. The mean of the two values thus obtained is taken as the true value. The source must, of course, remain in the same position when the switch Q is reversed.

It will be noted that the screens of the condensers are always connected together, so that any current in the thermo-junction, due to the capacities of the screens to earth, will remain constant. This permits connecting the outer lead B directly to earth, so as to render the process of tuning easier. The effect of using an earth has been tried on a large number of occasions, and has never produced any effect on the result, even at the highest frequencies of the order of 6000 kilocycles.

Owing to capacity currents the method is not reliable for measuring unscreened condensers, unless their capacities are of such magnitude that their impedance is absolutely negligible compared with the impedance of the capacity to earth. For unscreened condensers, therefore, a screened box was used, and the condenser measured when inside it. The use of such a screen will affect the capacity but not the effective series resistance. There are certain precautions to be taken in using the method. The principal one is that there should be no direct contact between the screens of the condensers.

An error can also be incurred owing to the different manner of tuning of the two circuits. In one case the condenser C_0 is varied and in the other it is the condenser under test. This will produce two slightly different conditions. The difference will always be very small unless the tuning is very blunt, but it is nevertheless advisable to keep the value of C_0 smaller than that of the condensers under test. If the thermo-junction T were placed immediately after the switch Q, this error would not occur, but it is not advisable to have unshielded instruments near the source. When, however, high resistance heaters are used in the instrument, it may be best to connect it between the switch Q and the lead B.

The leads between the condensers under test and the mercury switch S are at high potential and must be more specially considered. In the apparatus shown in Fig. 2 they pass close together between two brass plates, which are each connected to the nearest terminal of the thermo-junction and to one terminal of their respective resistances R, thus forming the connexion of R_1 and R_2 with T. In this way there are no dielectric losses in the neighbourhood of these wires. Small inequalities which were found at first disappeared completely when the brass plates were used.

The sensitiveness of the method depends on the sharpness of tuning and the deflection of the galvanometer. The accuracy obtainable can be readily estimated during the test by seeing by how much the deflection is affected on changing the resistance by a small amount. In order to increase the possible deflection of the galvanometer, when sufficient power is available to deflect it beyond the scale, a potentiometer P is inserted to supply a potential difference to counteract the E.M.F. of the thermo-junction and bring the deflection back on to the scale. By this means the sensitiveness is very considerably increased. It is normally possible to measure changes in the deflection due to a variation of 0·01 ohm in the resistance, or even less with suitable circuit conditions. When small condensers are measured at low frequencies this accuracy is not normally obtainable with galvanometers of ordinary sensitiveness, for the resistance of the coil L becomes excessive.

The advantages that may be claimed for the method compared with those depending on the variation of resistance or reactance are the comparatively high sensitiveness, the rapidity and ease of working, the possibility of measurements being carried out at frequencies of at least 6000 kilocycles and the freedom from errors due to reaction back on to the source. These latter errors are very often far larger than are supposed. In many methods, even when there is apparently good agreement over a number of readings (*e.g.* by using different resistances in the resistance variation method), the error may still be of the order of 5 per cent. or even 10 per cent., for it is not possible to use a sufficiently large range of values to be able to detect with any certainty the existence of discrepancies.

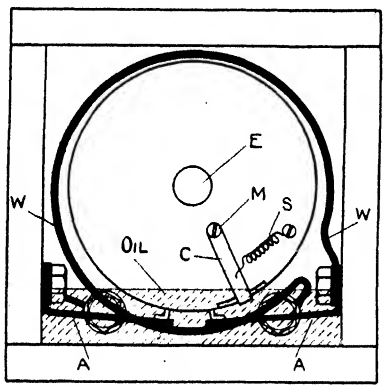
The method above described has been found reliable up to frequencies of 6000 kilocycles. That is, no change in the result has ever been found to occur by varying the coupling of the source or the position of the latter, by varying the thermo-ammeter, by using an earth, changing round the condensers being compared or by altering their relative distance apart. No doubt, if suitable corrections are applied to the resistance, still higher frequencies could be used.

The method is only suitable for the measurement of screened apparatus and could not be used for the measurement of coils, for instance, which are not usually screened.

2. Construction of the Resistances

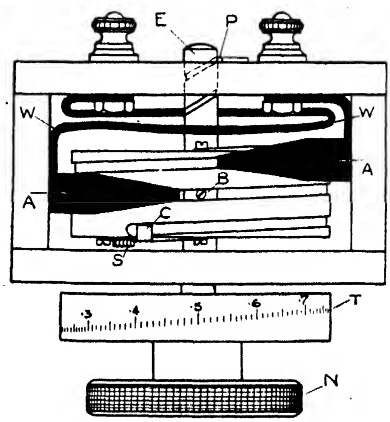
The resistances R_1 and R_2 consist each of a variable resistance with a scale graduated from 0 to 1·1 ohms and small mercury cups in series, in which fixed resistances made of very thin (No. 47 s.w.g.) manganin wire can be inserted. The resistance can be adjusted to any value up to the highest ever likely to be required for the purpose. The construction of the variable resistances is of special importance. In order that the resistance may not vary appreciably with frequency, it is necessary to use very thin strip. This makes it impossible for the brushes to press on the strip with sufficient pressure to obtain good contact in the ordinary way without fouling the strip. The principle used has been previously described by the author*. The original construction showed serious defects when left unused for a few weeks. This was overcome by a number of alterations. For the sake of completeness a description of the new instrument is given.

The variation of resistance is obtained by making part of the wire of copper and part of nickelin. The brushes are kept fixed and the wire moved, so that when the pointer is at zero



ELEVATION WITH SIDE REMOVED

FIG. 3.



PLAN WITH TOP REMOVED.

FIG. 4.

the wire between the brushes is nearly all copper, and when it is at 1·1 ohms the wire is nearly all nickelin. In this way the geometrical shape of the circuit remains absolutely unaltered. The instrument is shown diagrammatically in Figs. 3 and 4. The copper and nickelin wires rolled to a thickness of 0·05 mm. are wound round a continuous groove cut in a drum of bakelite. The groove makes two complete revolutions with a 1 cm. pitch. One end of each wire is soldered to a copper strip B and the other to two strips C pivoted at M, the wires being held taut by springs S. The brushes A are made of phosphor bronze with a small silver contact fitting very loosely in the groove. It is important that the brush contacts should nowhere touch the sides of the grooves. As the handle N is turned the bakelite drum advances while the brushes remain in the grooves. The axial motion is obtained by a pin P fitting in a screw thread cut in the spindle E of the drum. A scale is engraved on another drum T and read by means of a fixed pointer. The scale moves backwards and forwards, so that it is necessary either to have a long pointer or a scale engraved along a helical line. The whole is enclosed in an oil tight bakelite box and the contacts kept under very pure paraffin oil.

In the instrument as described, the current makes one complete turn of the drum and the

* R. M. Wilmotte, "A Variable Resistance for Radio Frequencies." *Experimental Wireless* 2 (1925) 684–686.

apparatus has, therefore, quite an appreciable self-inductance. This is counteracted by the thick copper wire W which is fixed, going from one brush round the drum to one terminal. This wire is always in circuit, so that the current flows in one direction round the drum and in the other direction along the wire W. The area enclosed by the current is thus very small.

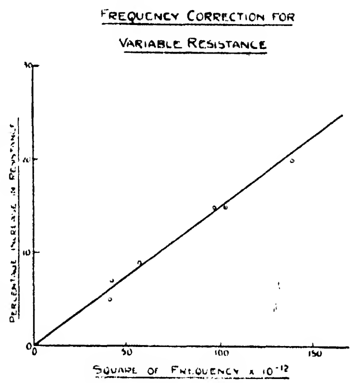


FIG. 5

The instrument has an appreciable zero resistance of the order of 0·1 ohm.

The employment of oil gives a very good contact, but there arises an important complication owing to the facility with which oil dissolves sulphur and the latter attacks copper. After a few weeks of remaining idle the contact resistance is often of the order of 2 ohms and can only be brought back by cleaning the wires with very fine sandpaper. This effect appears to be completely eliminated by using only bakelite in the construction of the instrument, and medicinal paraffin, on account of its purity, for the oil.

The variation of resistance of the instrument with frequency was tested by direct comparison with a very small length of Eureka wire 0·05 mm. in diameter. The results are shown in Fig. 5 plotted against the square of the frequency. This form of plotting was chosen because the skin effect should theoretically increase at first with the square of the frequency. It will be seen that the increase in resistance due to the skin effect is only 5 per cent. at a frequency of 6000 kilocycles.

3. RESULTS OF SOME TESTS

The method described above for the comparison of condensers has been used at the time of writing for over two years. Among the results obtained tests of three condensers have been chosen as examples. If the losses in a condenser can be represented by a series resistance r (ohmic loss) and a parallel resistance s, the total equivalent series resistance R is given by

$$R = r + \frac{1}{sC^2\omega^2} \qquad \text{......(1).}$$

If r and s are constant at a given frequency, plotting R against $1/C^2$ at constant frequency should give a straight line. This was found to be accurately the case, as will be seen from Figs. 6, 7, 9 and 11. In these figures the capacity is measured in micro-microfarads.

It should be noted that in the method of measurement used, only differences in resistance between the condenser under test and the standard condenser are measured. The standard condenser used when measuring condenser A was that employed by the author in a method for the absolute measurement of resistance by a thermal method*. It was there found that the effective resistance of the condenser at a capacity of the order of 600 $\mu\mu$ F. and a frequency of 600 kilocycles was of the order or less than 0·01 ohm. Condensers B and C were tested against another standard which gave a constant difference (nearly independent of frequency or capacity reading) of 0·04 ohm with the first standard used. For the author's purpose it was not required to know the absolute effective resistance of the condensers more accurately than to within a few hundredths of an ohm, so that the first standard condenser used was assumed to be perfect and a correction was applied when the other was used.

It will be noted from Figs. 6, 7 and 9 that the straight lines obtained all cut the resistance axis in the same point, and it would appear that the value of the effective series resistance at

* R. M. Wilmotte, "On the Construction of a Standard of High-frequency Inductive Resistance and its Measurement by a Thermal Method." *Proc. Roy. Soc.* A, **109** (1925) 500–522.

that point is equal to the term r of equation (1). The value of r then appears to be independent of frequency to within the limits of experimental error and the range of frequencies used. This does not necessarily mean that r is an actual series resistance, for a dielectric loss might vary with frequency in such a manner as to produce a similar effect. Such a variation, however, is not very likely.

CONDENSER A

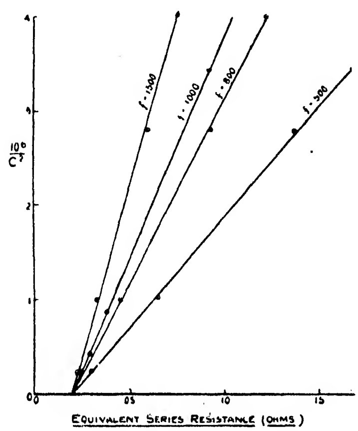


FIG. 6

CONDENSER A.

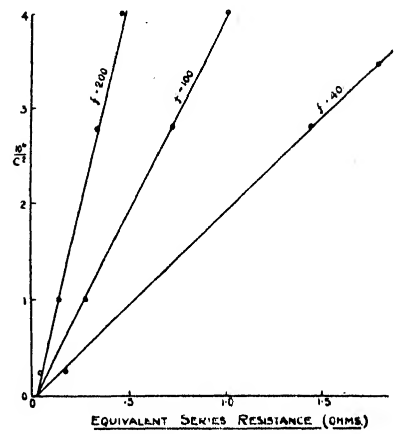


FIG. 7

CONDENSER A

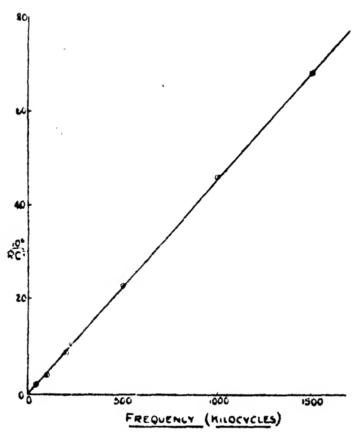


FIG. 8

CONDENSER B.

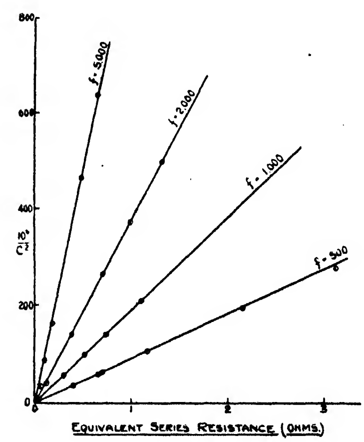


FIG. 9.

The gradient of the straight lines of Figs. 6, 7 and 9 should, from equation (1), represent $s\omega^2$, so that, if s is constant, we should find that plotting the gradient ($= 1/RC^2$) against the square of the frequency would produce a reasonably straight line. It is found, however, that $1/RC^2$ is very nearly proportional to the frequency, as will be seen from Figs. 8 and 10. This means that the shunt resistance s is inversely proportional to the frequency over the range used.

A description of the condensers may be of interest. Condenser A was tested when the method was first employed. It is a very large variable air condenser having amber insulation.

From Figs. 6 to 8 its effective series resistance R_A can be written as

$$R_A = 0{\cdot}02 + \frac{10^6}{46\,C^2 f} \qquad \ldots\ldots(2),$$

where the resistance is in ohms, the capacity in micro-microfarads, and the frequency f in kilocycles.

Condenser B is a variable air condenser of ordinary pattern as used on receiving sets. It has ebonite insulation, which has not been much exposed. The equation for its effective series resistance from Figs. 9 and 10 is given by

$$R_B = \frac{10^6}{0{\cdot}19\,C^2 f} \qquad \ldots\ldots(3).$$

In this case the series term r is too small to be measured.

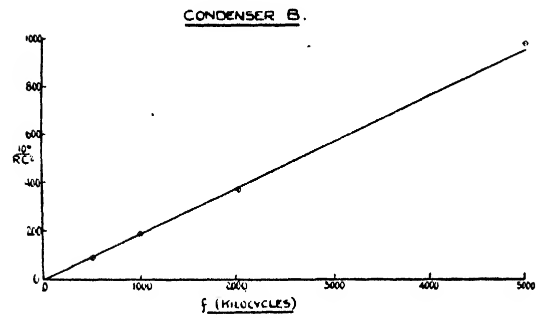


FIG. 10.

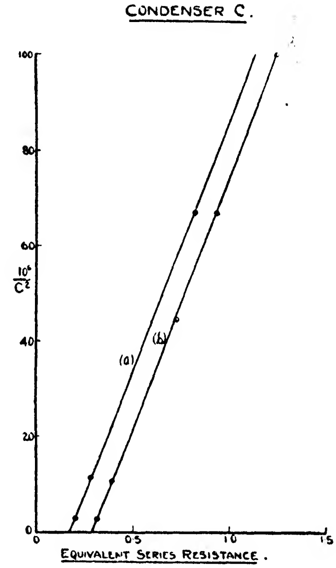


FIG. 11.

It is of interest to note, in connexion with condenser B, that the gradients of the curves of Fig. 7 appeared to vary slightly from day to day. The reason of this was traced to variations in humidity of the air. By blowing damp air on the ebonite insulation the effective resistance could be increased by as much as 15 per cent.

Condenser C is a variable air condenser with ebonite insulation, which has been much exposed. It has aluminium plates. The lines (a) and (b) in Fig. 11 show the effect of slightly varying the pressure between the plates. The gradient of the lines is about the same in both cases, but they cut the resistance axis in very different points. This shows that the series term r has changed, probably due to bad contacts between the aluminium plates.

The author has noticed that the series term r is often comparatively large in condensers having aluminium plates, though in certain cases they appear as good as brass plate condensers. One aluminium plate condenser in particular, which was used as a standard, was found to give a value of r as high as 0·08 ohm. On dismantling and thoroughly cleaning all the contacts this was reduced to 0·03 ohm. It will be interesting to note whether this value remains constant or increases in course of time.

In conclusion the author wishes to thank Messrs E. J. Pratt and A. C. Gordon-Smith who took many of the measurements. This work was carried out on behalf of the Radio Research Board, and is published by permission of the Department of Scientific and Industrial Research.

A SENSITIVE THERMO-REGULATOR. By D. H. BLACK,

Ph.D., M.Sc. Development and Research Laboratories, International Standard Electric Corporation.

[*MS. received*, 13*th July*, 1928.]

ABSTRACT. The paper gives a brief description of a simple thermo-regulator for the control of electrically heated air ovens.

The action of heat on a bi-metallic strip has long been used for the purposes of controlling temperature; but it was thought that a brief description of a sensitive thermo-regulator working on this principle might be of interest to those desiring to obtain a close control of the temperature of electrically heated air ovens. The instrument described below is simple in construction and forms a "one-hole fixing" for attaching to the door or a wall of an oven; and in addition it has none of the disadvantages associated with air bulb regulators.

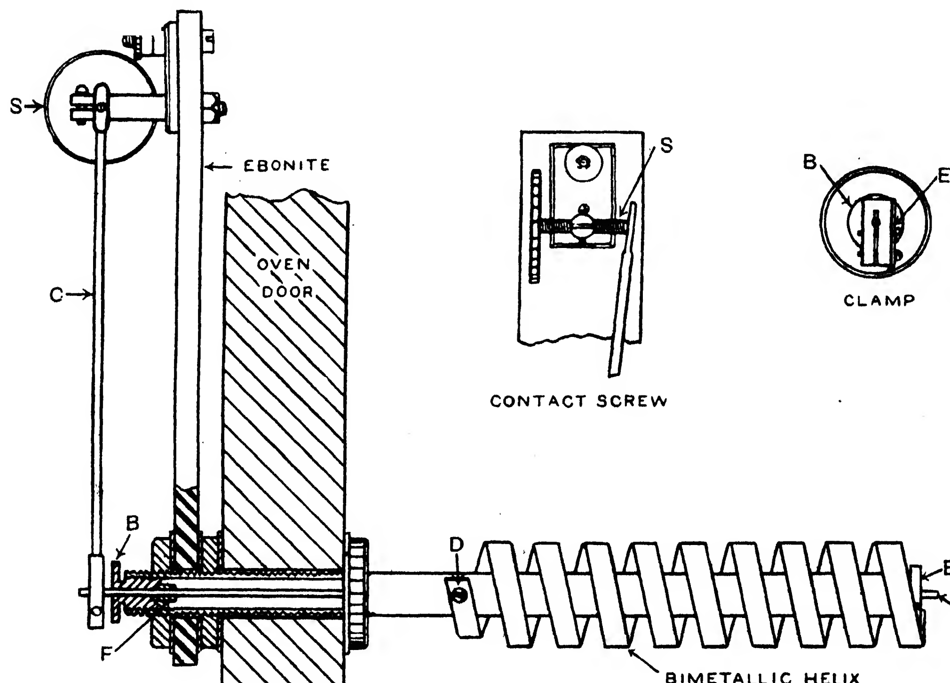


Fig. 1. Construction of Thermo-Regulator

The construction of the regulator can be seen from Fig. 1. When heated the bi-metallic helix, one end of which is fixed, receives a twisting movement which is conveyed to the contact arm, *C*, by means of the central steel spindle. On reaching the required temperature the arm makes contact with the screw, *S*, thus closing a relay circuit which cuts off all, or part, of the heating current. Rough adjustment for the temperature is made by clamping the contact arm on the spindle, and the final adjustment by means of the contact screw.

The main support of the regulator consists of a brass tube seven or eight inches long and about half an inch in diameter. This is fitted with two exactly similar end pieces, *BB*, which form bearings with the brass collars, *F*, sweated on to the steel spindle, *A*. For the latter a 1/16-in. steel knitting needle will be found convenient. One end of the tube is threaded for a distance of 3 in. or so, depending on the thickness of the oven walls, and fitted with

washers and knurled nuts by means of which it is fastened in position. A strip of ebonite $6\frac{3}{4}$ in. × 1 in. × $\frac{1}{4}$ in. is fitted to the outer end of the tube as shown, and this carries the contact screw and a terminal on its outer end. Aluminium rod 1/16 in. in diameter has been used for the contact arm; but the use of this material does not seem to be essential, especially if the arm is worked in a vertical position.

Bi-metallic strip of various widths and thicknesses, consisting of the permanent union of two metals having unequal coefficients of expansion, can now be obtained commercially*. Strip 0·25 in. wide and 0·02 in. thick will be found suitable, and a length of about 30 in. is wound around a rod to form a helix approximately 1 in. in diameter. For the contact arm to operate in the direction shown in the diagram the helix should be wound with the brass surface on the inside; but this is not essential as the contact screw, S, can be reversed if necessary. One end of the helix is fixed to the tube by means of the screw, D, and the other is attached to the spindle by means of the clamp.

The main source of trouble is in the bearings for the central spindle. It has been found that carefully grinding these with fine valve grinding material gives satisfactory results. Care should also be taken to make the length of the helix such that it causes no strain on the bearings. The contact arm and screw are tipped with some kind of contact metal; and a condenser with a resistance in series is connected across the gap to prevent sparking. The most suitable values for the condenser and the resistance will depend on the type of relay used, but a resistance of a few hundred ohms in series with a 2 μF condenser will be of about the right order. The relay circuit is completed through the body of the oven.

The sensitivity of the instrument is such that for a difference in temperature of 1° C. the tip of the contact arm moves through approximately one centimetre. Consequently it is possible to keep the temperature of an oven constant to within 0·1° C. with ease; and provided that sufficient care is taken in the adjustment of the bearings, and in the lagging of the oven and the circulation of the air inside it, it is possible to control the temperature to within 0·04° C.

REPORT ON THE OPTICAL AXIAL ANGLE AND RELATION OF ITS PLANE TO THE PLANE OF SYMMETRY IN MICA.

(REPORT REF.: D/T 16, RECEIVED FROM THE BRITISH ELECTRICAL AND ALLIED INDUSTRIES RESEARCH ASSOCIATION)

[*MS. received*, 19*th July*, 1928.]

INTRODUCTION

THE instrument described in the accompanying report was designed by Professor W. T. Gordon of King's College. The optical axial angles found for a representative series of micas given in Tables I and II were determined by Mr A. R. Everest of the British Thomson-Houston Company, by means of a specially arranged microscope, before Professor Gordon's instrument was built, but the results have been checked with the latter instrument and have been found to be in good agreement.

The instrument has been designed for rapid use and for cheapness. More elaborate apparatus may be more accurate but is not so easily manipulated.

* The bi-metallic strip used in this laboratory was supplied by The British Thomson-Houston Co.

The Optical Axial Angle

Mica is a monoclinic or pseudo-hexagonal mineral, but the muscovites and phlogopites are monoclinic and so can easily be differentiated from biotite, which is pseudo-hexagonal in character. When viewed between crossed nicols or in the tourmaline tongs one or two

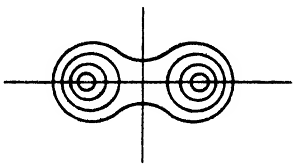


Fig. 1

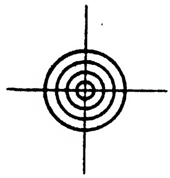


Fig. 2

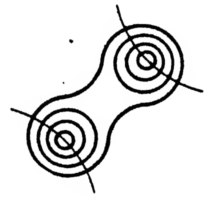


Fig. 3

sets of coloured concentric circles crossed by a black cross become visible. When only one set of circles and a black cross appear the mineral is uniaxial and is biotite as a rule. When two sets of circles and a cross are seen the mineral is muscovite or phlogopite or some other mica (other than biotite). In certain forms, like lepidolite, the mineral is almost uniaxial, so the circles appear like ellipses and the black cross has a very thick arm and a thin one.

The arms of the cross correspond to the vibration directions of the light emitted by the nicol prisms or tourmalines, and the rings are zones of equal interference for all rays of light entering at various angles. This is expressed diagrammatically in Figs. 1 and 2. Fig. 1 is the figure for muscovite and Fig. 2 for biotite. Except in the case of uniaxial micas, if the mineral is rotated the circles remain constant, but the black cross opens out into two hyperbolic curves—the brushes, as in Fig. 3. If the nicol prisms or tourmalines be rotated a similar phenomenon occurs, but if their planes be set at 45° to the vertical, then these brushes cut the horizontal line at right angles if the mineral be suitably placed.

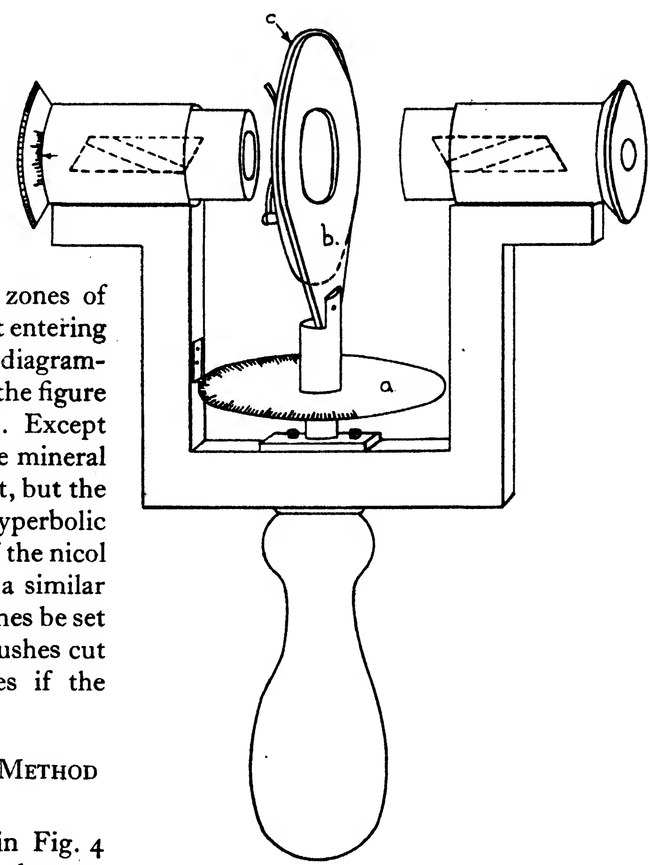


Fig. 4

Description of Instrument and Method of Using

The apparatus shown full size in Fig. 4 has been designed to effect these observations, and the angle between the optic axes can be measured by ascertaining the angle of rotation between the brushes. In the apparatus the nicol prisms are set at 45° to the vertical plane. The rotating stage *a* is marked out in divisions of 2 degrees each, but the single degrees may easily be estimated by inspection, and even half degrees can be estimated. The upright plate *b* serves to hold a second rotating stage *c* with clips to keep the mica plate in position.

When a mica fragment is placed on the vertical stage a series of coloured bands appears, and by a suitable rotation these may be made to cross the field parallel to the vertical direction; a rotation of the stage *a* will bring us to one of the "eyes" of the optic axial figure and the bands will now be a series of circles with one of the hyperbolic brushes passing through the centre of the innermost circle. Arrange this black line so that it stands vertically in the centre of the field. Note the angle on the circle *a*. Rotate until the second "brush" is in the centre of the field and again note the angle recorded in circle *a*. The difference gives the angle (in air) between the optic axes.

Monochromatic light is the most desirable, but in daylight the angle may be ascertained quite accurately enough for practical purposes. The thicker the sheet of mica the more numerous are the circles in each eye and the more distinct the brush.

The Axial Angle of Various Micas

In Table I the optical axial angles are shown for the muscovite micas, arranged in groups of the different colours, each group commencing with the clear and progressing towards the stained and heavily spotted varieties. It will be noted that when arranged in this way the optic angle is highest for the clear mica in any group, and lowest for the most heavily stained and spotted. It will also be noted that amongst the muscovites, the green micas apparently have the highest angle, ranging up to 72°, the ruby next, ranging to 69°, while the browns range up to 65°.

It has not been possible to make a similar grouping for the amber micas, phlogopites, shown in Table II. It will be seen, however, that the angle for the orange amber sample, No. 15, is about double what might be considered the average figure for amber, and it is of interest to note that it was predicted that this particular sample might be found to have characteristics, particularly as regards hardness, approaching those of the muscovite rather than the phlogopite.

In the last column of the Tables are shown the values obtained for hardness by the Shore test.

Table I. Muscovite Micas

Sample No. I.E.E. series*		Description	Angle between optic axes	Shore's hardness figures
Green	10	Green, clear, Madras	72°	92
	8	Green, stained, Madras	70°	92
	7*a*	Green, spotted, Madras	69½°	90
	67	Green, hydrated, Madras	68°	103
White	5	Soft white, Bengal	71°	87
Ruby	1*a*	Ruby, clear, Bengal	69°	93
	2	Ruby, slightly stained, Bengal	68°	93
	3	Ruby, stained, Bengal	68½°	88
	4	Ruby, heavily stained, Bengal	68°	97
	6	Ruby, spotted, Central Provinces, India	66½°	96
	16	Ruby, clear, Brazil	69½°	104
	17	Ruby, stained, Brazil	70°	76
	18	Ruby, heavily stained, Brazil	64°	86
Brown	11	Dark brown, clear, Madras	66°	106
	9	Light brown, stained, Madras	63½°	79
	7*b*	Brown, spotted, Madras	64½°	91
	7*c*	Brown, spotted, Madras	64½°	92
	7*d*	Brown, spotted, Madras	65°	97
	12	Brown, heavily spotted, Madras ...	64°	81
	7*e*	Brown, spotted, Madras	60°	90
	7*f*	Green-brown, spotted, Madras ...	60½°	94
	13	Green-brown, heavily spotted and stained, Madras	59°	93

* A collection of specimens of all these micas can be seen at the Institution of Electrical Engineers.

Table II. PHLOGOPITE MICAS

Sample No. I.E.E. series	Appearance by reflected light	Colour	Angle between optic axes	Shore's hardness figures
31	Shiny iridescent	Very deep amber	0°	—
45	Iridescent ...	Light amber	7°	—
44	Iridescent ...	Deep amber very nearly opaque	6°	—
40	Iridescent ...	Greenish, semi-opaque ...	0°	—
14	Semi-metallic	Amber	8°	77
39	Semi-metallic	Dark or blurred, semi-opaque	11°	—
38	Metallic ...	Amber, nearly opaque	11°	—
47	Metallic ...	Pale green	12°	—
37	Semi-metallic	Amber, dull	13°	71
42	Semi-metallic	Deep amber	16°	—
27	Shiny	Dark amber	16°	71
22	Shiny	Dark orange	21°	74·83
46	Shiny	Amber, blurred	20°	—
15	Shiny	Light amber	25°	101

The optical axial angle of muscovite micas varies between 55° and 75°, that of phlogopite micas between 5° and 25°, and that of biotite micas between 0° and 5°. The measurement of this angle is the most satisfactory method of determining the class to which a mica belongs.

ULTRA-VIOLET MICROSCOPY. By L. C. MARTIN, D.Sc.

Assistant-Professor, AND B. K. JOHNSON, Demonstrator in the Technical Optics Department, Imperial College of Science and Technology. (*Continued from p.* 344.)

Investigation of Difficulties

As mentioned above, there was no difficulty in finding the ultra-violet focus on a film, but when the correction found from the film was used to step straight from the visual setting to the ultra-violet focus for a plate, the result was not always successful. The chief possible contributory circumstances to be examined were:

1. Stability of object on stage.
2. Stability of surface of stage relatively to the objective carrier.
3. Mechanical inefficiency of slow motion mechanism.
4. Mechanical inefficiency of objective changing device.
5. Variation of refractive index of immersion fluid.

In regard to 1 the method of holding the slide on the stage was improved by filing away the centre of a supporting ledge and adding a strong spring clip. After this was done, the slide could even be cleaned *in situ*, the focus remaining the same before and after.

The apparatus is very sensitive to pressure on the table near the toes of the instrument; the test is very easily made with the fixture described in the next section. When this sensitiveness was realized greater care was made to avoid touching the table in this region; but there are creeping effects probably due to temperature and humidity changes which may warp the table gradually, while temperature changes may distort the framework of the microscope. The bed-plate casting would naturally obviate some of these troubles.

Items 3, 4, and 5 will be dealt with in separate sections.

Calibration of Slow Motion

A simple interferometric arrangement had been supplied by the makers in previous instruments which registered the displacement of the objective bracket with respect to the

mechanical slide on which it moved, but for general use we desired to be able to find the displacement of the objective with regard to the stage, and the arrangement adopted is shown in Fig. 8. Mercury green light is reflected from the transparent plate R, when interference rings are found between the adjacent surfaces of the plate P and the small lens L; these are viewed by the auxiliary microscope. Thus any displacement of the objective carrier relative to the stage is accompanied by a contraction or expansion of the rings, and can be measured by counting the number which appear or vanish at the centre. "One ring" indicates a displacement of $\lambda/2 = 0{\cdot}273\,\mu$, corresponding to nearly three divisions of the drum.

The lubricant at first used for the screw may have been too thick. A calibration curve was made for the fine adjustment by taking forward and backward movements controlled by counting 40 fringes, readings of the drum being taken for every 4 fringes; the results of this are given in Table III, (*a*). The order of readings is *down* in the first column and *up* in the second. Note that there is a hysteresis error of some 17 drum divisions, although there was no apparent immediate loss of time or back-lash evident on reversing the screw. The

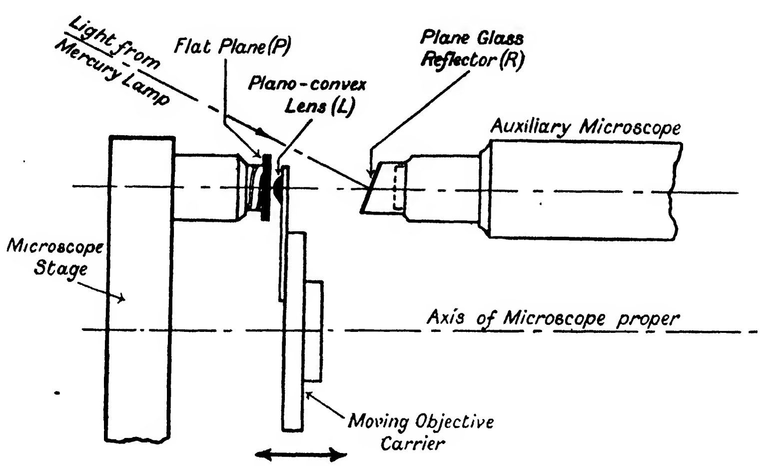


Fig. 8

mechanism embodies a spring to take up back-lash. The most likely cause of the trouble was a gradual squeezing of the lubricant from between certain of the surfaces, for after cleaning and relubrication the trouble largely disappeared, as will be evident from Table III, (*b*). The error is now reduced within three drum divisions, an amount comparable with the inherent errors of observation.

Table III. *Results of Calibration of Fine Adjustment*

	Before cleaning Readings (*a*)		After cleaning and relubrication Readings (*b*)	
Fringes	Forward	Back	Forward	Back
0	3·74980	3·74812	5·17637	5·17661
4	3·75090	3·74920	5·17746	5·17771
8	3·75185	3·75032	5·17860	5·17881
12	3·75280	3·75150	5·17971	5·17990
16	3·75390	3·75268	5·18079	5·18099
20	3·75485	3·75378	5·18187	5·18206
24	3·75591	3·75496	5·18293	5·18311
28	3·75695	3·75615	5·18403	5·18416
32	3·75801	3·75740	5·18516	5·18525
36	3·75905	3·75865	5·18626	5·18634
40	3·76010		5·18746	—

Objective Changing Device

This device was shortly described above and, so far, no other has been tried. Separate trials have shown that after practice it is usually possible to remove and replace the apochromat without a visible change of focus. There are, however, occasions when sudden and irregular changes of focus do occur in removing one objective and replacing the same; it seems possible to ascribe these to failure to get the planed surfaces properly into contact, perhaps through bending or slipping of the surrounding ring or its extension, which has occasionally been found to ride up above the "plane" of the objective holder. This point calls merely for an improvement in the details of the design. It is proposed to try an objective changer designed on geometric principles, similar to that described by Professor Pollard*, as soon as possible, but the changing of the objectives is only necessary, under our present methods, in special cases, and as it must inevitably be a possible source of difficulty, it is hoped that methods will ultimately be devised to dispense with this procedure entirely.

It must be remembered that the design of the present instrument is directed towards a most difficult end, the photomicrography of filter-passing organisms; we have had no experience of such work up to the present, and nothing in this paper may be taken as any criticism of methods hitherto developed and used for such a purpose. It is clear, however, that there are many "easier" classes of objects for which a simpler procedure may suffice.

Focussing with Fluorescent Eye-piece

The so-called fluorescent or searcher eyepiece may be more strictly termed a fluorescent eye, as it consists essentially of a small quartz lens at the focus of which is a piece of uranium glass, this retina (as it were) being viewed by an ordinary Ramsden eye-piece of glass. The whole is mounted as one unit and can be brought up suitably behind the eye-piece of the microscope, the quartz lens of the "eye" being made to coincide with the exit pupil.

This piece of apparatus did not at first appear to be of any real help in the determining of the ultra-violet focus, except in such cases where the object had very definite transparent and opaque portions—for example, a line drawn on a silver film. When, however, the more usual semi-transparent object is used, it is quite impossible to see the object at all with the fluorescent eye-piece. By the application of a simple device similar to that used by Lucas† in connexion with his work on opaque objects, it has been found possible to use the fluorescent eye-piece with transparent and invisible objects to such effect that it is not necessary to employ the visual apochromat at all. The method consists in making a small carbon line on the underside of the quartz cover glass before it is cemented down, this being so opaque to the ultra-violet radiation that it can be readily seen and focussed when using the fluorescent eye-piece. Having made use of the carbon in this way, it can be removed from the field by a slight adjustment of the mechanical stage and the photographs then taken. This procedure has proved highly successful both in the saving of time and in the certainty of obtaining the object in focus on the plate at the first attempt. Fig. 11 shows a photomicrograph taken by this method. An alternative device, of use in special cases, is to place in the slide one or two specks of gold leaf about $0{\cdot}5\,\mu$ thick.

In any case a group of four photographs with varying settings is always advisable, as the precision of fixing the focus by the fluorescent method is naturally low and the error may be four or five times the depth of focus. There are, however, many "objects" which do not lie all in one plane; one part may be in focus even if other parts are indistinct. Furthermore the pronounced curvature of field is often helpful in this respect. Using the "$\times$ 10" eyepiece and a flat object like a silver film, the range of focus between the central parts and the

* *Proc. Opt. Convention*, **2** (1926) 1000.

† Reprint B. 200, July, 1926. Bell Telephone Laboratories, U.S.A.—F. F. Lucas.

outer parts of the image corresponds to a movement of the objective (nearer the slide) of 20 drum divisions or 2μ. Very often the necessary alteration of focus to obtain central definition can be judged from the first photograph; then again with object slides containing bacteria the actual thickness of the organisms may be greater than the depth of focus. Thus in practice the difficulty, which seems at first so great when the physical depth of focus is considered, is to some extent discounted as far as the actual production of reasonably "sharp" pictures is concerned. The interpretation of the pictures is, however, quite another matter.

Control of the Immersion Fluid

Taking a cover glass of average thickness, 0·19 mm., the working distance between the front lens of the monochromat and the surface of the cover glass is approximately 0·25 mm.; this space must be filled with the immersion fluid (glycerine solution has usually been employed hitherto) which has to be adjusted, for homogenous immersion, to have the same refractive index as that of fused quartz for the particular ultra-violet "line" employed. At 20° C. this refractive index for $\lambda = 0{\cdot}275\mu$ is 1·4961.

Consider a monochromat of $NA = 1{\cdot}3$; the divergence angle of the extreme ray will be about 60°, and in our case the linear path difference in the immersion liquid of axial and marginal rays will be

$$0{\cdot}25\ (\sec. 60° - 1) = 0{\cdot}25 \text{ mm.},$$

and taking the change of optical path just sufficient to cause an observable change of focus to be $\lambda/4$ we get for the corresponding change δN of refractive index,

$$\begin{aligned}\delta N\,(0{\cdot}25) &= 0{\cdot}275 \times 10^{-3}/4\\ &= 0{\cdot}00027, \text{ or when the } NA = 1{\cdot}2,\ \delta N = 0{\cdot}0004.\end{aligned}$$

A change of refractive index of this amount, taking place while the objective is in position, will therefore be just sufficient to cause a perceptible change of focus; this would require a displacement of about one drum division ($0{\cdot}1\,\mu$) to restore the focus.

In the visible region the sensitiveness of the focus to changes of refractive index is naturally less; for a lens working at NA 1·2, δN becomes about 0·0007 for the visual region. This would require a change of focus of about two drum divisions to restore the focus; the relation between change of refractive index and corresponding change of focus is about the same for the same NA; when the visual lens works at a reduced aperture, a movement of one drum division will compensate the effect of a relatively greater change of refractive index.

These figures are only very approximate, but they give an idea of the required constancy of refractive index of the medium.

Interpolation from a recent series of measurements* for a glycerine-water mixture gave the following results:

$$N_{\cdot 275} = 1{\cdot}4961,\quad N_{\cdot 546} = 1{\cdot}4544,\quad N_{\cdot 589} = 1{\cdot}4530.$$

The glycerine-water mixture adjusted to give homogeneous immersion is strongly hygroscopic under ordinary atmospheric conditions, and a drop of it spread out on a glass surface may easily change in refractive index by 2 units in the third place in one minute. If the surface exposed is more limited the altered liquid will diffuse inward from the outer layers and will cause irregularities of refractive index.

In cases when it was desired in early trials to keep the refractive index of the immersion liquid more constant, a loose cylindrical housing was fitted over the front of the monochromat objective so that the liquid immediately between the objective and cover glass could be insulated from the air, the junctions being "sealed" with the immersion fluid; this

* *Trans. Opt. Soc.* **29** (1927–8) 1.

proved successful in maintaining much more constant conditions, but its use entailed a certain amount of risk of shifting the slide while bringing the housing into position.

In the discussion on the paper referred to above, Colonel Gifford mentioned the use of a solution of dextrose where a liquid was required for a cementing medium which was non-hygroscopic and was also transparent to the ultra-violet. Arising out of this suggestion, cane-sugar and dextrose solutions were tested for their transmission of the ultra-violet, and were found to absorb very little in the region of $\lambda = 0{\cdot}275\,\mu$. A series of refractive index measurements for cane-sugar solutions was then undertaken by the apparatus and methods previously described; the results are given in the following table, for a 60 per cent. solution and two of greater concentration, the last being nearly saturated. Measurements were made at laboratory temperature, which was kept as near to 20° C. as possible.

Table IV. *Refractive Indices of Cane-Sugar Solutions*

A		B		C	
λ	Refractive index	λ	Refractive index	λ	Refractive index
·6563	1·4553	·6563	1·4473	·6563	1·4394
·5893	1·4574	·5893	1·4495	·5893	1·4416
·4861	1·4626	·4861	1·4546	·4861	1·4468
·4341	1·4668	·4341	1·4588	·4341	1·4507
·320	1·4865	·400	1·4638	·380	1·4575
·285	1·4976	·350	1·4721	·275	1·4837
·275	1·5023	·275	1·4935	·265	1·4889
·260	1·5106	·260	1·5010	·250	1·4972
·245	1·5199	·248	1·5080	·240	1·5041

The results given in the above table are of a provisional nature, and will be supplemented by further measurements made under more carefully controlled conditions as opportunity allows. A simple interpolation gives $N_D = 1{\cdot}4516$ for a solution which has $N_{\cdot 275} = 1{\cdot}4961$.

It is clearly possible to obtain an immersion fluid from a solution of cane-sugar, but a trial with the refractometer showed that such solutions (and even dextrose in the necessary strength) evaporate very quickly in ordinary conditions. A simple step is to make a mixture of the glycerine solution and the sugar solution in the necessary proportions to be non-hygroscopic and non-evaporating. If a series of mixtures in various proportions is prepared they will evaporate or absorb until equilibrium is reached, but with a change in temperature or humidity they will undergo a corresponding change. In one experiment 10 c.cm. of glycerine solution was placed in each of four tubes and proportions of 1, 1·5, 2, and 2·5 c.cm. of sugar solution were added and mixed. The refractive indices were taken with an Abbe refractometer. Samples of the resulting solutions were exposed to the air for a week and the refractive indices again measured. The figures were:

Proportion of sugar ...	1·0	1·5	2·0	2·5
Original N_D of mixture ...	1·4529	1·4528	1·4528	1·4527
N_D after 7 days' exposure	1·4497	1·4509	1·4527	1·4540

The third mixture is evidently very near the original strength, and would be expected to give homogeneous immersion for fused quartz at $\lambda = 0{\cdot}275$. In order to check the validity of the use of these mixtures under the same conditions as the glycerine, practical trials have been made to measure the focus correction between the visual apochromat and the monochromat using (*a*) glycerine solution, (*b*) sugar solution, (*c*) various mixtures. The required correction agreed within two drum divisions in all cases, and no systematic difference could be detected under the limits of accuracy of the experiment.

The procedure adopted in practice is to make up a series of ten mixtures, samples of

which are exposed continuously to the air in a dust-free cabinet. The original refractive index on mixing is determined by the relative proportions of the solutions and is checked by the Abbe refractometer; the percentage of glycerine ranges from 60 per cent. to 95 per cent., and this covers all the solutions which have been required in a five-months' experience of temperature and humidity variations.

To select an immersion liquid on any day it is only necessary to select from the range the mixture which has its refractive index nearest the original normal value; this is easily done in two or three minutes by the aid of the Abbe refractometer.

In order to appreciate the relative stability of the mixture in equilibrium, an experiment may be made to examine a drop in the Abbe refractometer, and then to expose the wet prism surfaces to the air for one minute, when a reading is again taken; and so on for ten successive exposures of one minute. This done, the experiment may be repeated with the glycerine solution. Fig. 9 shows the result of such a trial.

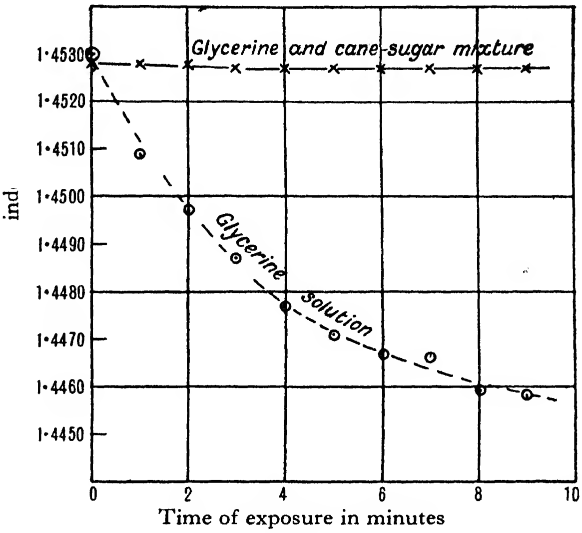


Fig. 9

In the process of changing objectives, which is always necessary at present with certain slides, some of the immersion liquid is inevitably smeared on the side and often on the surface of the stage; with glycerine, or any solution rapidly changing in refractive index, and used in this way the film of liquid is undoubtedly liable to lack homogeneity, and a slow change of focus due to this cause is inevitable; these troubles, however, are very largely overcome in the manner described above.

Method of Measuring Resolving Power of Microscope Objectives

During the progress of the work one of the authors developed a method* whereby a numerical value for the resolving power of microscope objectives could be obtained, with the intention of attempting to determine how much increased resolution was actually being obtained by the use of shorter wave-length illumination. Briefly the method consisted in forming a reduced image of a grating situated at the correct tube-length of an auxiliary microscope objective and employing this image as the object for the lens under test. By rotating the grating the apparent distance between the lines of the "object" is varied and a position found when resolution just ceases, from which the line separation is obtained.

This method has now been employed for testing the resolving power of a quartz objective (6 mm.) with ultra-violet illumination, and although space does not permit in this paper a full description of the method employed and the figures obtained, it can be stated here nevertheless that this 6 mm. quartz monochromat of $NA = 0{\cdot}35$, with ultra-violet illumination $\lambda = 0{\cdot}275$, gave a resolution value of 0·00039 mm., whilst a 4 mm. glass achromat NA 0·71 in wave-length 0·51 μ gave 0·00036 mm.; thus showing that the resolution of a $\frac{1}{6}$ in. objective in green light can be equally well obtained by an objective of half this numerical aperture when used with ultra-violet illumination ($\lambda = 0{\cdot}275\,\mu$).

* Some introductory experiments dealing with a quantitative method of determining the resolving power of microscope objectives. B. K. Johnson, *Jour. Roy. Micro. Soc.* June, 1928.

Further experiments are being carried out in connexion with the measurement of the resolving power of the quartz objectives, including the testing of a higher power, namely a 2 mm., by adaptation of the method for use with the vertical illuminator.

Typical Results

Figs. 10, 11 and 12 will illustrate some typical results. Fig. 10 gives comparative photomicrographs at the same magnification made respectively by a 2 mm. apochromat by Zeiss (*NA* 1·3), using blue light ($\lambda = 0{\cdot}45\,\mu$), and by the 2 mm. monochromat, *NA* 1·2, using ultra-violet radiation ($\lambda = 0{\cdot}275\,\mu$). The object is a portion of a silver film mounted on a cover glass of fused quartz. The original negative was taken at a magnification 800; the enlargement is "four times."

The illumination in the "visible radiation" photograph was effected by using an immersion lens (*NA* 1·2) as condenser, the slide in this case being replaced by an ordinary cover glass on which the object was re-mounted. It was necessary to use rather a long tube-length for the apochromat, but the conditions then seemed satisfactory, and there is nothing to explain the markedly finer detail of the ultra-violet photograph beyond the shortness of the wave-length. The white "dots" in the photograph represent diffraction disks due to ultra-microscopic apertures in the film.

Fig. 11 represents "leather fibres" at a magnification of 3000, and Fig. 12 shows a group of staphylococci (stained) at the same magnification. The slides were prepared by members of the first instructional course held in the subject of ultra-violet microscopy at the Technical Optics Department, who have made many interesting photographs. The "carbon-line" method of finding the focus has been very successful; it was employed in Figs. 11 and 12. The interpretation of the images will not be discussed at present.

Successful photographs of metallographic specimens have also been made, but experience has not yet shown the best methods of working; the control of the illumination calls for considerable study, and it may well be that the apparatus should assume a radically different form for this special purpose.

It is feared that the photomicrographs will not reproduce very well, but the originals will gladly be shown to anyone who is interested.

In conclusion it may be said, as a result of the experience gained through the work of the members of the class, who have essayed the application of the method to many different types of object, that there are undoubtedly many cases in which very useful information can be obtained by ultra-violet microscopy which could not be gained in other ways; one outstanding example is the investigation of the structure of fine grained materials which may be of importance in industrial processes; the possibilities in regard to biological investigations need no emphasizing, and those in regard to metallography are undoubtedly equally great. The rapidity with which the practice is likely to extend depends to a great extent, however, on the possibility of simplifying the method and apparatus and reducing the cost of the latter. Many lines of possible improvement and development are recognized, and work on these is in progress.

This paper would be incomplete without an acknowledgment of the great assistance of Sir Herbert Jackson, Chairman of the Technical Optics Committee, and Professor Rankine, Director of the Technical Optics Department, who have done much to make the work possible, and also of our colleagues Professor Conrady and Professor Pollard, whose friendly advice and assistance have been most helpful. Our sincere thanks are also due to Mr J. E. Barnard for valuable help and advice.

(*Concluded*)

(*a*) λ = 0·45 μ. 2 mm. apochromat

(*b*) λ = 0·275 μ. 2 mm. quartz monochromat

Fig. 10. Comparison photomicrographs of silver film. × 3200 (enlarged × 4 from negative)

Fig. 11. Leather fibres. × 3000. λ = 0·275 μ

Fig. 12. Staphylococcus (stained). × 3000. λ = 0·275 μ

NEW INSTRUMENTS

A DEMONSTRATION EYE-PIECE

THE Demonstration Eye-piece described (Fig. 1) was made by Messrs W. Watson and Sons, Ltd., at their Barnet Works, at the suggestion of Professor R. C. Gale of the Military College of Science, Woolwich. It takes the place of the ordinary eye-piece, and is designed to allow simultaneous observation of the structures of alloys or other micro-specimens by demonstrator and student.

To effect this object, use is made of a reflecting prism system similar to that used in the high-power binocular microscope made by the same firm. An Huyghenian eye-piece fitted

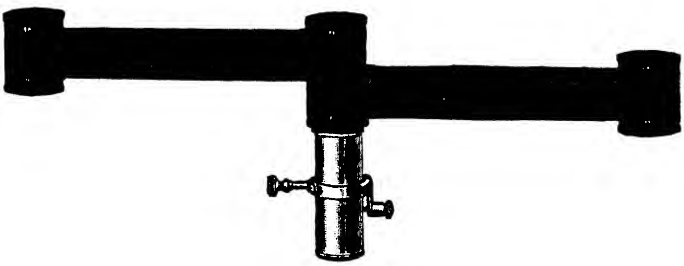


Fig. 1

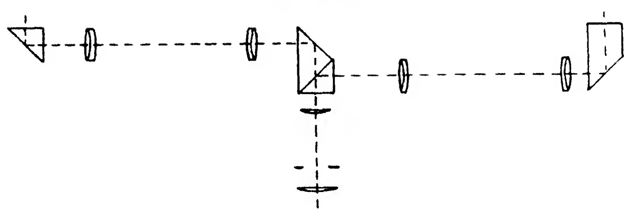


Fig. 2

with an adjustable pointer and a screw for clamping to the microscope tube is surmounted by a compound half-silvered prism which divides the light into two equal ray systems (Fig. 2). To the right and left of the compound prism are two lateral tubes containing telescope systems of unit magnification, each composed of two achromatic lenses. Reflecting prisms at the outer ends of the tubes enable the observers to see the images in the usual direction, the distance between the eye positions (12 in.) being ample. The two images are well defined and equally bright. The eye-piece may be recommended to all whose duty it is to demonstrate and describe micro-specimens in detail.

A NEW MICROAMMETER

MESSRS FERRANTI, LTD., Hollinwood, Lancashire, whose 2½ in. instruments intended mainly for radio use are widely used for this and innumerable other purposes, have now extended their series to include a microammeter, which is also a galvanometer.

For very sensitive testing a reflecting galvanometer will always be indispensable, but for a considerable amount of work such great sensitivity is not only unnecessary but disadvantageous, on account of the higher cost of the instrument, lack of robustness and overload

capacity, and slowness of working. This new instrument has been developed to fulfil the want for a relatively cheap, sensitive, portable and quick-acting galvanometer for null tests, and is extended to be also a calibrated micro-ammeter.

The scale is about 110° arc, has a central zero, and is calibrated 250–0–250, and reads 10 microamperes per division. It is remarkably robust, and being fitted with double pivots it requires no levelling and its overload capacity is high. The damping is such that in use it is nearly critical. On open circuit it is under-damped and on short circuit overdamped. It has a resistance of 60–70 ohms. The illustration shows how it is mounted for use, with its attached leads.

A NEW BINOCULAR MICROSCOPE

For microscopical examinations in research work and for many industrial purposes an ordinary microscope is not always the most convenient form of instrument to use. Where a high magnifying power is essential, with its necessary special methods of illumination by

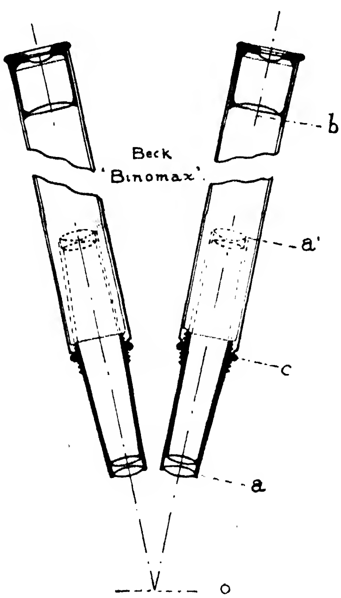


Fig. 1

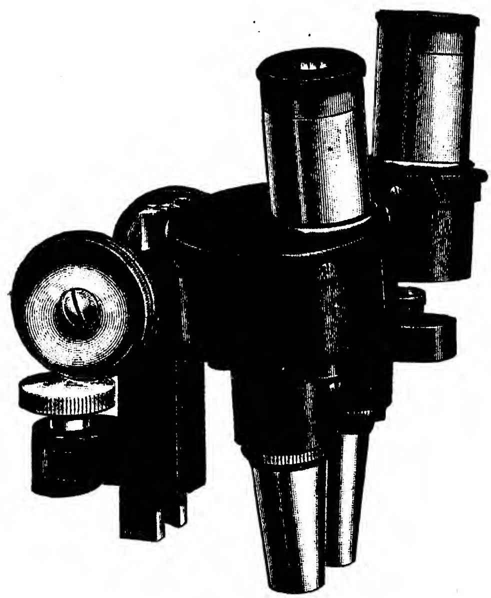


Fig. 2

achromatic condensers, dark ground or vertical illuminators, it is necessary to use a microscope of the usual type and which possesses the adjustments necessary for the proper use of this apparatus; but for some purposes magnification is not necessary, and often the character, shape and size of the articles do not lend themselves to placing upon the stage of a microscope, nor can they be prepared in a manner suitable for examination on an ordinary microscope. For these purposes a binocular microscope mounted on a special stand is often found to be of the greatest service. Such an instrument gives a very wide field of view, has

long working distance, gives an erect image and very marked stereoscopic vision. Thus the view obtained is a natural one, being similar to that seen by the two eyes except that it is on a larger scale. With many objects this is of great advantage, as it gives an idea of depth and shape which cannot be obtained so readily with a monocular instrument.

The instrument here described, The Beck Binomax (R. and J. Beck, Ltd., 69, Mortimer Street, London, W. 1), is of the binocular type, but it utilizes a patented optical system, which is new, in order to obtain four magnifying powers with only one pair of object-glasses and two pairs of eye-pieces.

The Binomax consists of two complete microscope systems inclined to each other at the natural convergence of the eyes. Each system has a prismatic erecting arrangement. The object-glasses are held in tubular mounts with the lenses at one end. Each object-glass is so threaded that it can be placed in the microscope body in two ways, one way having the tubular mount projecting out of the body, and the other with the mount inside the body. By this means the distance between object-glass and eye-piece is made to differ very considerably, and widely different powers are therefore obtained. The optical performance is not interfered with as the object-glass by this process is reversed. By the use of two pairs of eye-pieces, also of different powers, four powers are therefore obtained with the same object-glasses, these powers being × 4, × 8, × 16 and × 32.

Fig. 1 illustrates the principle upon which the Binomax is made. The object-glass (*a*) is shown screwed on to the body with its lenses projecting in front of the microscope. In dotted lines the position (*a′*) is shown into which it can be screwed in the interior of the body. The image is formed by this object-glass at a position (*b*) and is examined by the eye-piece. The point (*o*) is the position of the object. The distance between the object (*o*) and the position (*a*) and the distance between (*o*) and the position (*a′*) are so arranged that (*oa*) is equal to (*a′b*) and (*oa′*) is equal to (*ab*). The image is therefore in focus at (*b*) whichever way the object-glass is screwed on to the body, but different powers are obtained. If the object-glass is corrected to work in the position (*a*), it will also work in the position (*a′*), and provided that the lenses are reversed, which is done by reversing the whole mount, the optical corrections are in each case equally perfect. In a binocular instrument the object must lie at the intersection of the two optic axes of the microscopes, and the change in power is therefore made without altering the distance between the object and the bodies of the microscope.

The following table gives the working distances and field of view of the Binomax:

Magnifying powers	Working distance mm.	Diameter of field of view mm.
× 4	110	33
× 8	110	22
× 16	75	9
× 32	75	5

The actual apparatus is illustrated in Fig. 2, which shows the microscope unit which can be fitted to any of the special stands made by means of the lug and clamping screw at the back of the instrument. The interocular distance is adjusted by revolving the prism boxes as in the Greenough type of microscope, and the focussing is by rack and pinion.

A variety of stands is made for using the Binomax to suit different conditions of work.

Perhaps the most useful form is the table clamp stand (Fig. 3) or the table stand with base (Fig. 4). In these stands an upright is provided, held in the one case by a clamp on to the edge of the table, or in the other supported by a heavy iron tripod base. Up and down this slides a cross-piece which can be rotated around the upright, and can also be clamped at any desired height. This cross-piece has running in it a bar to which the Binomax is

attached. The cross-bar can be rotated and adjusted to any position and clamped. The arrangement gives practically universal motions, and a Binomax mounted on either of these stands is a most suitable instrument for examining small portions of large objects such as pottery, engineering parts, prints or museum specimens, where the article can be placed upon a table and the microscope adjusted into a convenient position to examine the particular part which is of interest. A stand is also made for dissecting purposes (Fig. 5), which consists of a horseshoe base with a glass plate held upon it by means of spring clips so that it can be readily removed. The glass plate forms an excellent stage for dissecting, and if it is removed, the microscope can be placed over a large surface if it is required to examine this.

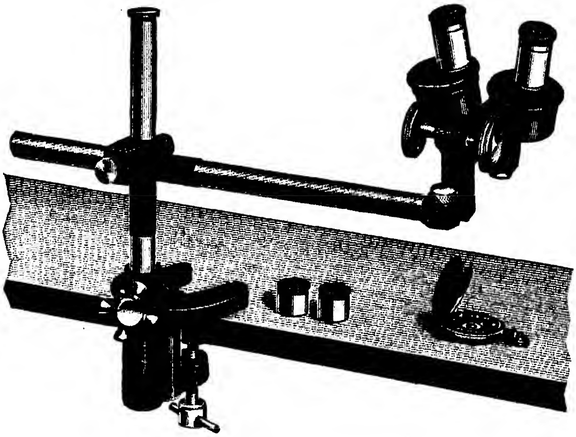


Fig. 3

Another dissecting stand is shown in Fig. 6, which consists of one of the "Crescent" dissecting microscopes with a Binomax attached to it. The microscope can be swung aside and another arm brought into position, in which an ordinary dissecting magnifier can be used. This stand has a very firm base

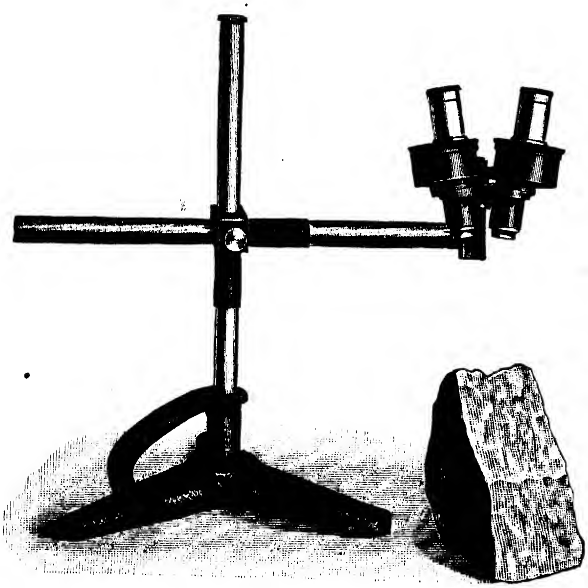


Fig. 4

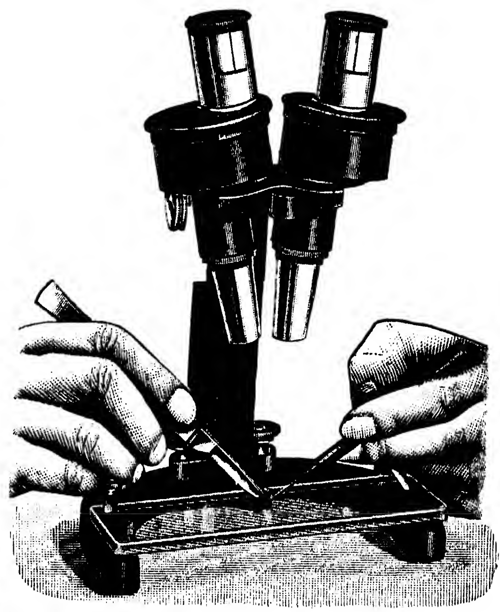


Fig. 5

and hand rests and also has a double mirror, silvered one side and opal the other, for illuminating the object.

Another form of stand (Fig. 7) has the Binomax mounted on what is practically an ordinary microscope. It has a heavy horseshoe base and a square stage, and is provided with a joint for inclination and a double mirror for illuminating objects.

A lighting attachment is made which, as will be seen in Fig. 7, is fixed to a lug in the

front of the microscope. This employs a small low-voltage electric lamp which can be run off accumulators or direct off the current supply by means of a suitable resistance.

It will be seen that with this selection of stands a binocular microscope of this type can be used for a great variety of work and under many different conditions. In medical work it is an excellent means of examining skin, hair or bone, and makes a good corneal microscope and a useful dissecting instrument. In a museum a great number of objects in stone, wood and metal, and also specimens in troughs and dishes can be examined. In other branches

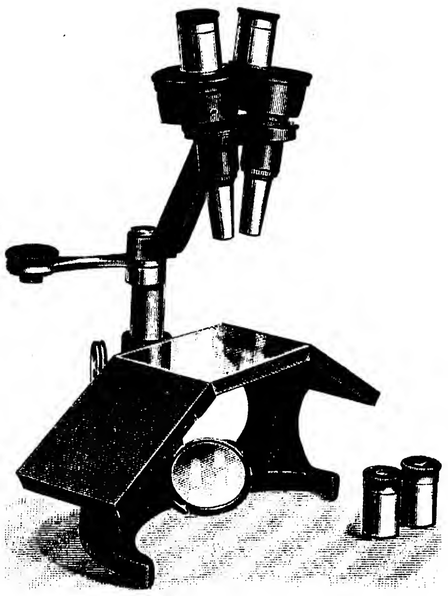


Fig. 6

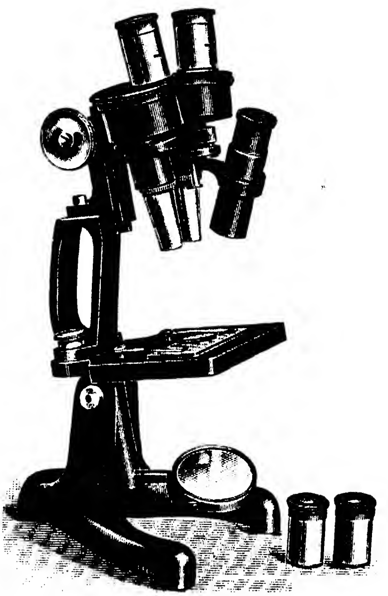


Fig. 7

of work dealing with such things as flaws in metals, brushwork in paintings, prints and engravings, fabrics and fibres, this microscope is of great service. In engineering shops small mechanical parts are easily examined, and in many works where very fine precision turning is done, a microscope with universal movements fitted to the lathe itself will prove most valuable.

LABORATORY AND WORKSHOP NOTES

A TRANSFORMER FOR THE FILAMENT CURRENT OF HIGH TENSION RECTIFYING VALVES. By E. P. HUDSON AND P. M. S. BLACKETT. The Cavendish Laboratory, Cambridge.

When using large diode valves for rectification in high tension circuits, the provision of a large capacity filament heating battery and the necessity of insulating it from earth are decided inconveniences. For example, a G.E.C. Rectifying Valve E.H.T. 3 takes a filament heating current of 8 amps at 8 volts, and the insulated large capacity battery required is cumbersome. A more convenient arrangement is to heat the filament with alternating current from the secondary of a specially constructed step-down transformer, the primary of which is connected to the A.C. supply. Several transformers of a very simple type have been constructed in this laboratory and have proved satisfactory.

A photograph of one designed for use with a G.E.C. Rectifying Valve E.H.T. 2 is shown. This valve takes about 3 amps at 6 volts and will stand about 40,000 volts. The transformer, for an A.C. supply of 200 volts at 90 cycles, consists of a ring core of stalloy stampings of mean diameter 18 cm. and section $2{\cdot}5 \times 2{\cdot}5$ cm., wound with a primary of about 600 turns. The secondary consists of about 20 turns bound together into a ring of diameter 21 cm. The ring interlaces the primary and is at no point less than 7 cm. from it. This air gap is sufficient to stand a peak voltage of about 60,000 volts. The secondary is supported on three ebonite pillars and the leads from the secondary are taken direct to the filament. The valve itself and the secondary coil are, therefore, all that need high tension insulation. The output is controlled by a 300-ohm sliding resistance and an A.C. ammeter in the primary circuit.

CAPACITY IN THE DRYSDALE'S BRIDGE. By S. S. H. NAGIR AND P. N. SHARMA. University of Lucknow.

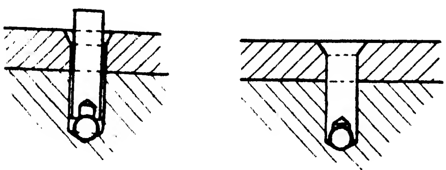
THE Wheatstone's bridge encloses various areas which naturally possess different self-inductances. The exact value of these will depend upon the disposition of the various arms of the bridge in any actual experiment. Drysdale's bridge seeks to minimize this inductance effect by making the enclosed area as small as possible, the four chief terminals being enclosed within a square of nearly an inch in side. If connexions to these terminals, from other components used, are made by means of bell-wires, the inductance is very efficiently eliminated.

The distribution of the stout copper pieces in the Drysdale's bridge, however, includes capacities which are not negligible in comparison with the infinitely small capacities we sometimes meet with in wireless circuits, and which we wish experimentally to determine. This fact was accidentally discovered by us. One terminal only of a capacity was connected with one arm of the bridge, the other terminal being left open and the balance point obtained. It was found, however, that the balance point remained undisturbed when the small capacity was removed altogether.

The capacity was found to be of the order of 220 $\mu\mu F$. All the four arms gave almost identical values. When the experiment was repeated eight months after, at the moment of dispatching this note, it was found to be 88 $\mu\mu F$, the two values being in the ratio of 2 : 5. This is an appreciable amount in comparison with the values to be determined for parts of wireless circuits; the smallest capacity that the present writers had occasion to measure being of magnitude 65 $\mu\mu F$.

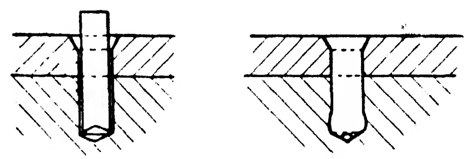
RIVETTING INTO BLIND HOLES. By H. G. FLORY, M.I.Mech.E.

The accompanying illustrations show three methods of securing rivets into blind holes. That shown in Fig. 1 (which is very similar to a method described in a recent issue of this *Journal**) has, to the writer's knowledge, been in constant use in America for at least three years. The principle is that the specially shaped end of the rivet is upset in the bottom of a hole into which an ordinary steel ball has been placed. When the rivet is driven in, the ball expands the one end of the rivet, whilst at the same time the other end is being burred over to secure the loose plate or part. *A* shows the rivet, ball, hole and plate before the operation and *B* illustrates the result after driving in.



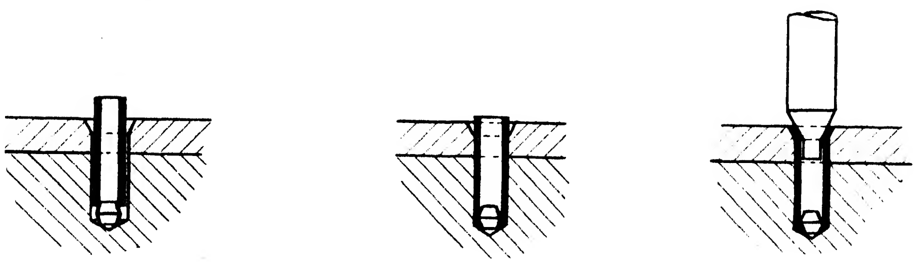
A *B*

Fig. 1



A *B*

Fig. 2



A *B* *C*

Fig. 3

As an outcome of the above, the writer evolved the method shown in Fig. 2, and his firm has been using it for over two years. It was found desirable to dispense with the steel ball, as, especially in oily hands, it became very elusive, and it was not always easy to ascertain if the ball had been placed in the hole or not. Consequently, when relying on the average workman, some holes had two balls and some had none! The second method shown overcame these difficulties. In eliminating the use of the ball it was found necessary only to countersink the end of the rivet, as illustrated. *A* and *B* show the rivet "before" and "after" the rivetting operation. The swelling shown in *B* can actually be seen under a magnifying glass. So popular is this type of rivet that the writer's firm keeps a good stock of them, in various suitable sizes and lengths. They are made in quantity on "Brown and Sharpe" automatic machines.

Another method, shown in Fig. 3, was put forward by an assistant of the writer, and has been used with success on light work. As seen by referring to *A*, the rivet is in the form of a tube and the ball of Fig. 1 is replaced by a small pellet. *B* shows the bottom of the tub secured after the second operation of rivetting, and at *C* the punch is shown expanding the top of the tube to secure the loose plate or part. A good substitute for the small pellet is a short length of taper pin of suitable diameters.

* July, 1928, *Rivetting into a Blind Hole*, by the Taylor-Hobson Research Laboratory.

CORRESPONDENCE

LONG PERIOD MOVING COIL GALVANOMETERS

By permission of Mr D. C. Gall and of the writer we publish the following extracts from a letter addressed to Mr Gall:

I was very much interested in reading your article "A Long-Period Galvanometer," appearing on page 280 of the September 1928 issue of the *Journal of Scientific Instruments.*

You will be interested in knowing that we have upon the market a form of our high sensitivity galvanometer making use of the principles outlined in your article. We have a U.S. patent covering this method of sensitivity control, the first claim of which reads as follows:

"The method of decreasing the torque exerted by its suspension upon a galvanometer coil deflecting in a magnetic field which comprises modifying the magnetic field in which the coil moves to effect upon the coil in opposition to the torque of the suspension a torque due to the action of said magnetic field upon magnetic material disposed in said field and controlled by said suspension."

The patent number is 1,587,010.

In writing this letter my purpose is not particularly to call your attention to our patent, but simply because I thought you would be interested in having additional information on the very interesting phenomena which you have independently observed.

LEEDS AND NORTHRUP COMPANY
4901, STENTON AVENUE, PHILADELPHIA

C. S. REDDING, *Vice-President*

REVIEWS

Abderhalden's Handbuch der biologischen Arbeitsmethoden. Abt. III, Teil A, Heft 6: Elektronen- und Ionenröhren. By Ferdinand Scheminzky, Vienna. Urban and Schwarzenberg, Berlin and Vienna, 1928. pp. 442, 239 figs., index, literature. Price Mk. 25.

Notable contributions have been made to the separate branches of science by the interchange of ideas and by the migration of workers from one branch to another. Following the ante-natal union of the fundamental subjects of mathematics and physics we find physics and chemistry overlapping in an ever widening common territory embracing biology in its march, with the consequence that the subject of physical chemistry permeates all the natural sciences. It is little wonder that a description of the laboratory methods available to biologists should reach the dimensions already attained by the authoritative production under the general editorship of Dr Emil Abderhalden. The comprehensive nature of the work may be realized from the fact that this present volume is but one of ten in the third section—which deals with Physical Chemistry—of a work which has now run to thirteen sections.

The recent developments in wireless telephony which have contributed so much facility to radio communication have incidentally placed at the disposal of the laboratory worker new devices for attacking special problems. In view of the elusive and fluctuating character of the changes in living matter it is no occasion for surprise to find that the biologist is always early in welcoming new methods for attacking his problems. The appearance of this volume by Scheminzky is a timely occurrence, and although the subject dealt with is expanding at an astounding rate yet he has managed in these four hundred pages to give a good account of the present state of development of the thermionic valve and the glow lamp.

The reader unacquainted with these two devices will find a descriptive account of their construction and mode of working written from a non-mathematical standpoint, and although the valves and related components described are of continental type no difficulty will be encountered by the English reader if he refers to the descriptive brochures of our own valve manufacturers, who produce a range of valves with a variety of characteristics which are unexcelled. Practical details for the operation of valves are abundantly supplied, *e.g.* six methods of obtaining grid bias are figured and described, thus enhancing the value of the book as a laboratory manual, a result due entirely to the obvious handling by the writer of the apparatus described. An account of the application of the valve to the measurement of various electrical quantities is included. The main part of the writer's labours is, naturally, devoted to the presentation of the applications of the thermionic valve to biological investigations; a very comprehensive selection of such uses is taken from the literature, references to which are given, and which are presented in a readable manner: a short account of the writer's own devices is also given. The volume, which is invaluable as a work of reference in a biological laboratory, contains large portions which are sure to interest the physicist since biology is so personal a study. D. T. H.

The Rise of Modern Physics. By HENRY CREW, PH.D. Fayerweather Professor of Physics in Northwestern University. Pp. xvi + 356. 36 illustrations. London: Baillière, Tindall and Cox. Price 22*s*. 6*d*. net.

The plan of this book is most attractive. It is described as a "popular sketch," and is stated in the author's preface to contain the substance of a course of lectures on the history of physics addressed to undergraduate students.

To call the work a "popular sketch" does it, I think, less than justice, for it implies a "popular" audience, and the reader who has no special knowledge of science may find that the author has assumed, perhaps unconsciously, a knowledge of physical theory and scientific method beyond his range. The value of a book of this kind seems to be rather to the student of physics, who takes it up with some foreknowledge of the subject, and will find in it that historical and biographical background which is too often lacking in a university course in any branch of science, but which nevertheless adds enormously to its interest.

Dr Crew has brought, to the composition of this volume of three hundred odd pages, wide reading, an evident love of the subject, and a pleasing style. He traces the development of physical theory and practice, through a series of chapters, from the earliest times up to the period of the modern work in spectroscopy and atomic physics. Chapters are given to Greek and Roman Science, to Arabian Physics and the Physics of the Middle Ages. The birth of modern physics he finds in the work of the great trio, Newton, Galileo and Huygens. There follow sections on the experiment and theory upon which the sciences of light, electricity and magnetism and heat have gradually been built, leading up to recent physics by paths that are familiar to many. The excellence of the method lies in its linking up of the achievements of each individual with the work of those who have preceded and followed him, preserving thereby a connected and coherent account of the growth of physical science; and in the biographical material and the frequent references to and quotations from original publications, giving to the book a literary quality which is wholly admirable. The text is assisted by an interesting series of illustrations. To those of us who are proud of the part which Englishmen have taken in this great adventure, this impartial history from across the Atlantic is stimulating; and if in some few particulars we may be inclined to differ from the author in his distribution of credit, the effect is probably salutary and refreshing.

For a book which should find many readers the high price is regrettable. Although printing and illustrations are good, it is difficult to understand how a charge of twenty-two shillings and sixpence for a volume of this size can be justified. T. M.

Volumetric Glassware. By VERNEY STOTT, B.A., F.INST.P. London: H. F. and G. Witherby. 8vo. Pp. 232. Price 20*s*. net.

This volume forms a valuable addition to a series of books on Glass and Glass Technology under the general editorship of Professor W. E. S. Turner, Professor of Glass Technology in the University of Sheffield. The accuracy of volumetric glassware has in the past often been taken for granted, a trust which experience has shown to be misplaced except in the case of apparatus calibrated by

public authorities such as the National Physical Laboratory, Teddington, or the Reichs-Anstalt, Berlin. The author of this book, who is a senior assistant at the former establishment, commences by outlining the development of a satisfactory unit of volume which should be simple to determine, and free from ambiguity in its definition.

The kilogramme was originally defined as the mass of water, at the temperature of maximum density, occupying 1 cubic decimetre or 1 litre; but owing to the experimental difficulty of accurately determining this relationship, a standard "Kilogramme des Archives" was constructed, and finally adopted as the basis for the definition of the litre. Subsequently, confusion arose in the use of the term "cubic centimetre" as a submultiple unit of volume, measuring vessels adjusted to contain an apparent weight of 1000 grm. of water at room temperature often being marked as containing 1000 c.c., but actually containing 1002 c.c. This led to the suggestion, by the Committee for the Standardization of Scientific Glassware in 1924, of subdividing the litre into 1000 millilitres (m.l.), thereby avoiding confusion, a course which has been widely adopted.

Methods are then described for the determination of the capacity of glass measuring vessels by weighing, formulae being given for the necessary corrections for variations of temperature and pressure from the standard conditions. Tables are given to facilitate these calculations. The following three chapters give the methods used in the examination and calibration of flasks, measuring cylinders, pipettes, and burettes, most of these being methods used in the test-rooms of the National Physical Laboratory. These are divided into Class "A" for vessels of the highest accuracy, and Class "B" where only commercial accuracy is required, tables of tolerances being specified for the various types of vessels. The next chapter deals with the methods used by the manufacturer in the graduation and permanent marking of glassware. A preliminary waxing is followed by the cutting of the graduation or other marks, usually by the use of dividing engines, and engraving machines applying the pantagraph principle, or in some cases by hand. These marks are then rendered permanent by etching with hydrofluoric acid.

The errors introduced into volumetric analysis by the use of inaccurate measuring apparatus are next considered in a number of typical cases, assuming the maximum tolerances allowed in Class "A" apparatus, and the cumulative effect of successive errors. The work is completed by a useful series of tables for converting the weights of 1 to 2000 millilitres of water, weighed under various conditions, to the weights at 15° C. and 760 mm. pressure; and of the corrections to be applied to barometer readings for variations in temperature. The only criticisms that can be made are the lack of an index, and the poor quality of the few half-tone illustrations. These are not up to the high standard of the line drawings and engravings which form the bulk of the forty illustrations. The book can be well recommended to all who are interested in the manufacture or use of volumetric glassware.

R. C. G.

Report on an Enquiry into Apprenticeship and Training for the Skilled Occupations in Great Britain and Northern Ireland, 1925–26. VI, Engineering, Shipbuilding, Ship-repairing and other Metal Industries, pp. 204, price 7*s*. 6*d*. net. VII, General Report, pp. 194, price 5*s*. net. London: H.M. Stationery Office.

The Ministry of Labour have issued a very complete report on apprenticeship in the Engineering and Allied Industries. Included in this report is a section dealing with Scientific Instrument Making, which has of late been generally treated as a branch of engineering.

Dealing with the report as a whole, we learn that 74·9 per cent. of the boys employed in the engineering industry are recognized apprentices, but when we go on to read that considerably more than half of the agreements are merely verbal, it is obvious that the description must be considered somewhat loosely, as verbal agreements can have little real value, and legally none at all. It is also brought out in the report that, again dealing with the industry as a whole, the larger firms employ a lesser number of boys than do the smaller ones, though there are important exceptions. In a large number of the sub-industries discussed, the number of apprentices or learners employed is governed by trade union agreements or restrictions, and, speaking generally, these restrictions are more often recognized by the larger firms than by the smaller ones.

In the Scientific Instrument Making industry there are no recognized restrictions, and most of the agreements between the principal firms and the unions came to a sudden end with the General Strike of 1926. The enquiries of the Board of Trade regarding instrument making were made altogether from 40 firms, employing in the aggregate nearly 13,000 male workpeople, of whom 1609 were apprentices or learners; and from 32 firms, employing about 2300 workpeople, with no apprentices

or learners. It must not of course be assumed that these latter firms employ no boys; it is probably the case that they take in lads in the first place as errand boys, and that these gradually get sifted into the factory without any specific agreements. Of the 1609 recognized "learners" more than one-half were in electrical work, as we should expect to be the case, having regard to the large number of boys engaged in the manufacture of wireless components.

As apparently the Board of Trade have only acquired knowledge of a total of 139 apprentices in the instrument trade with *written* agreements, it is obvious that the old system of indentures is almost a thing of the past in the industry. Writing with a considerable knowledge of the trade, it may be said that this does not imply that employers are at all blind to the duty of training a requisite number of lads, but as a rule it has been deemed better to retain the right of dismissal without legal formalities. The old days, be they good or bad, when an employer could (and sometimes did) chastise a troublesome apprentice, are gone for ever, and it has undoubtedly been found in practice that unless the right of summary dismissal is retained (however seldom it may be exercised), that workshop discipline may suffer. The same is true of adult labour. Many of us are anxiously asking whether the increasing number of railway accidents is not due to this very cause.

The considerable number of boys engaged on very cheap and low grade electrical work is a matter for disquiet. It cannot be good that so many lads are being trained to a poor standard of excellence. Fortunately the days of cheap wireless gear would appear to be passing, and the marked tendency for purchasers to prefer apparatus of higher grade, which is apparent to-day, will probably reduce somewhat the proportion of juvenile labour employed; but the balance will be to the good.

R. S. W.

The National Physical Laboratory. Collected Researches. Vol. xx, 1927. H.M. Stationery Office. London: Kingsway, W.C. 2. Pp. v + 444, Quarto. Price 18*s*. 6*d*. net.

The present volume of the *Collected Researches of the National Physical Laboratory* is devoted entirely to the subject of Optics. It embraces the papers in this subject which have been published in the course of the past five or six years, usually in the *Proceedings* of scientific societies. There are thirty papers in all, twenty-two from the Optics department, seven from the Electricity department, and one from the Metrology department.

When optical systems of fine performance are produced it is not without deep-seated prior investigation on the theoretical side. The range of instruments is vast, and equally varied are the problems which have to be solved in order to produce them in a form very nearly approaching perfection, and afterwards in devising adequate methods of test. In the course of thirteen papers Mr T. Smith gives an exposition of principles and many examples of their application to important questions of design, from complex photographic lenses down to eyeglasses. High commendation is given to the new methods, initiated and developed by the late S. D. Chalmers, for the testing of lenses by means of interference fringes. Very striking too is the record of work detailed in the course of eight papers contributed by Mr J. Guild, which represent great advances in the domain of Colorimetry. Full descriptions are given of many new instruments designed by him and constructed in the Laboratory. These include a visual spectrophotometer, a trichromatic colorimeter, a vector colorimeter, and a flicker photometer for heterochromatic photometry; as well as an interesting method of measuring the coefficients of expansion of optical glasses, enabling a change of length of a twentieth of a wave-length of green light to be observed, and yet evading the tiresome procedure of counting interference fringes. Papers in Photometry, by Dr J. W. T. Walsh, include the examination of diffusion of light by a circular disc, based on Dr W. E. Sumpner's treatment of the whitened globe, and confirmed by an independent method; and the completion of a thorough investigation into the cause of fading of luminescence in radio-active compounds. It is interesting to observe the great range of brightness to be covered in photometric measurement, from 0·004 candle to 160,000,000 candles per square metre. Further papers in the volume deal with the difficult question of colour temperature and its relation to luminous efficiency, and with the performance and design of the optical system of ships' navigation lights. The concluding paper is a valuable one by Mr G. A. Tomlinson on measurement by optical projection, treated experimentally and theoretically, and involving, for example, applications to screw thread measurement and to the determination of the centre of gravity of a bullet.

This impressive volume, excellently printed in a large type, represents an output of work of the highest value, and constitutes a magnificent contribution to the literature of Optics. D.O.

THE ROYAL SOCIETY

The following papers were read at the meeting on November 1st:

E. B. Moullin, "An Ampere Meter for Measuring Currents of very high Frequency."

C. V. Boys, F.R.S., "Solid Dipleidoscope Prisms." Supplement.

The following abstract is of a paper read at the meeting on November 15th:

F. H. Rolt and H. Barrell, "The Difference between the Mechanical and Optical Lengths of a Steel End-Gauge."

The paper describes an investigation of the relation between mechanical, geometrical and optical lengths of end or block gauges constructed of steel. A knowledge of the difference between mechanical and optical lengths of such gauges is necessary in order to derive mechanical lengths from optical interference methods of measurement, which entail reflection of light from the measuring faces of the gauges.

A set of block gauges is optically measured by an interference method. By comparing the sum of the optical lengths of the single gauges with the optical length of a wrung combination of the same gauges, the average difference between mechanical and optical length of a gauge may be derived. The results closely confirm those obtained by Pérard and Maudet at the Bureau International in so far as difference between geometrical and optical lengths (or the phase loss at reflection) is concerned, but they disagree with these observers' value of the difference between mechanical and optical lengths. It is shown that the new value is more consistent with previous work (*Proc. Roy. Soc.* A, vol. 116, p. 401, 1927) than that obtained by Pérard and Maudet, since the latter leads to a negative value for the thickness of a wringing film.

THE OPTICAL SOCIETY

At the meeting of the Society on November 8th a paper by L. C. Martin, D.Sc., A.R.C.S., and T. C. Richards, B.Sc., A.R.C.S., was read on "The Relations between Field Illumination and the Optimum Visual Field for Observational Instruments."

The paper described some experiments based on the application of the results of recent studies on "spatial induction" in vision to determine the conditions governing the optimum size of visual field under certain conditions. The results have a bearing on recent efforts greatly to enlarge the fields of view of binoculars, indicating that small fields are better under certain conditions.

THE PHYSICAL SOCIETY

The following papers have been read at recent meetings of the Society:

November 9th, "An Absolute Current-Balance having a Simple Approximate Theory," by L. F. Richardson, D.Sc., F.R.S., V. Stanyon, B.Sc., and other students of Westminster Training College.

Abstract. A simple form of current balance has been constructed which, when tested by experimental comparison with a standard ohm and Weston cell, measures currents with a probable error of about 1 part in 1000. The calculation of the force acting on the moving coil of the balance involves no pure mathematics beyond that of the Intermediate B.Sc. The coils are single layers so that they can in the future be made as precise helices. Actually we have had to aim at cheapness rather than at perfection, and so irregularities of shape leave the current uncertain by 5 parts in 1000. A second approximation, depending on a simple deduction from Laplace's equation, corrects the elementary theory by 1·4 parts in 1000 of current.

November 23rd. "A New Alternating Current Potentiometer of Larsen Type," by Albert Campbell, M.A.

Abstract. The instrument is a modification of the simple Larsen A.C. Potentiometer, in which the unknown voltage is balanced by another (v_2) of the form $(r + j\omega m)\, i_1$, where i_1 is a constant

standard current and r and m are resistance and mutual inductance, both variable. In the simple type the quadrature component $\omega m i_1$ is obtained by multiplying the observed $m i_1$ by the pulsatance ω (*i.e.* $2\pi \times$ frequency). The new system avoids this trouble by ensuring that at any given frequency the current through the primary of the mutual inductance shall be such a multiple of i_1 as to make the balancing voltage $(r + jbM) i_1$, where M is the mutual inductance and b a constant. This is achieved by an arrangement of loop-shunt, which can be set for any given frequency so that the readings of r and bM shall give the two components directly in millivolts. The standard alternating current i_1 is set and held constant by a thermal null method in which it is balanced against a known direct current.

CATALOGUES

ADAM HILGER LTD, 24, Rochester Place, Camden Road, N.W. 1, send a new edition of Section 3 of their General Catalogue, dealing with Echelon Diffraction Gratings, Echelon Spectroscopes, Lummer-Gehrcke Parallel Plates, and Special High Resolving Power Accessories for spectroscopy. Special attention is drawn to the Reflection Echelons of Platinized Fused Silica which are now listed. Largely owing to the development of interferometric methods of testing, in which Messrs Hilger have been concerned, the standard of best optical work has improved considerably in recent years, and the construction of these Echelons has become possible. The suggestion of Mr W. E. Williams of using a number of fuzed silica plates of equal metrical thickness placed in optical contact has been adopted, and Messrs Hilger have been successful in constructing a reflection Echelon having full theoretical revolving power.

A separate pamphlet from Messrs Hilger relates to Dr Jean Thibaud's X-ray Grating Spectrograph for the study of Soft X-rays and of the Extreme Ultra-Violet, of which instrument some examples were expected to be ready in November. By the tangential use of the grating, according to the method of Dr Thibaud, diffraction spectra of X-rays may be obtained with a ruled grating.

We have received the first number of the *Technical Instrument Bulletin*, described as a journal devoted to optical and allied instruments as applied to Industry, Research and Medical Science, and published by A. G. FREWIN, Diamond House, Hatton Gardens, London, E.C. 1, in collaboration with the EMIL BUSCH OPTICAL COMPANY LTD. The first issue, of some sixteen pages, contains articles on "The Colour Film in Medical Instruction," by Dr A. Schafer; "Choice of Magnifications in Microscopy and Photomicrography," by Prof. F. Hauser; "Optical Instruments for Testing Works Materials," by H. Ehlert; and "Instantaneous Photography of Living Micro-Organisms," by A. G. Frewin. Readers who wish to receive the publication, free of charge, are invited to send their names and addresses to the publisher.

THE LEEDS AND NORTHRUP COMPANY, 4901, Stenton Avenue, Philadelphia, U.S.A., send their *Bulletin* No. 434; Students' Kelvin Bridge, which has been extensively revised. The instrument has been specially designed for use in the educational laboratory, for teaching the Kelvin bridge method for measuring low electrical resistances accurately. *Bulletin* No. 434 gives a general description of the bridge and of its method of operation, and includes a price list of the instrument and its accessories.

A. GALLENKAMP AND CO. LTD., 19 and 21, Sun Street, Finsbury Square, London, E.C. 2, send their list, *S.S.* 1, of surplus laboratory apparatus for experimental work in Light, Sound and Electricity. Prices are quoted for many of the items in quantities.

MAX KOHL, A. G., Chemnitz (Germany), Adorfer Strasse 20, have sent their Price List No. 100, Volume II of Physical Apparatus for the Mechanics of Solids, Liquids and Gases, the Wave Theory, Acoustics and Optics. This list is in English, and is a well printed and illustrated volume, showing an extensive range of laboratory apparatus of all kinds.

LABORATORY AND WORKSHOP NOTES

READERS of the *Journal* are reminded that notes concerning laboratory or test-room methods, and workshop devices or methods of utility to instrument-makers are welcomed, and that ten shillings will be paid for each such note published.

NINETEENTH ANNUAL EXHIBITION OF THE PHYSICAL SOCIETY AND THE OPTICAL SOCIETY

As previously announced the Nineteenth Annual Exhibition of the Physical and Optical Societies is to be held on Tuesday, Wednesday and Thursday, January 8th, 9th and 10th, 1929, at the Imperial College of Science, Imperial Institute Road, South Kensington, and will be open in the afternoon from 3 p.m. to 6 p.m., and in the evening from 7 p.m. to 10 p.m.

Over eighty firms have accepted the invitation to exhibit in the Trade Section at this Exhibition, and in addition a group of research and experimental exhibits is being arranged, which will be shown by Fellows of the Societies and others, and by a number of research laboratories and other institutions. Some interesting historical exhibits will also be included.

The discourses, which will be given at 8 p.m. on each evening, are as follows:

On January 8th: Professor F. Lloyd Hopwood, M.A., F.Inst.P. "Experiments with High Frequency Sound Waves."

On January 9th: Mr Conrad Beck, C.B.E. "Lenses."

On January 10th: Mr A. J. Bull, M.Sc., F.Inst.P. "Some Colour Problems in Photo-Engraving."

We understand that invitations to the Exhibition have been sent to the Institution of Electrical Engineers, the Institution of Mechanical Engineers, the Royal Aeronautical Society, the Royal Meteorological Society, the Faraday Society, and a number of other societies and bodies. As in previous years members of these societies should apply for tickets to their secretaries. Others may obtain tickets on application to the Secretary, the Physical and Optical Societies, 1 Lowther Gardens, Exhibition Road, London, S.W. 7. Tickets are required only on January 8th and 9th. Admission on the third day, January 10th, will be without ticket.

SPECIAL EXHIBITION NUMBER

Following the usual practice of the *Journal* the February, 1929, issue will be a special Exhibition Number of 48 pages devoted to the above Exhibition. By special permission of the Exhibition Committee the number will contain the Discourses, which will not be published in full elsewhere; and the different classes of exhibits will be described in illustrated articles specially written by authorities in the branches of scientific work to which they relate.

JOURNAL OF SCIENTIFIC INSTRUMENTS. BACK NUMBERS

Two shillings per part will be paid for clean, undamaged copies of parts 1, 2, 4, 11 and 12 of Volume 1 of the *Journal*. These should be sent to the Secretary, Institute of Physics, 1 Lowther Gardens, Exhibition Road, London, S.W. 7.

NOTICE TO SCIENTIFIC INSTRUMENT MANUFACTURERS

In order to keep readers of the *Journal* in touch with the latest developments in scientific instruments, the Editor would be glad if all manufacturers of such instruments would keep him informed of all new instruments or important improvements in their productions as soon as they appear, either by sending him catalogues, pamphlets, or circulars concerning them, or in the case of important developments, by letting him have concise special descriptions of their construction and performance. Descriptions of light machine tools suitable for instrument work would also be appreciated.

INDEX TO VOLUME V

* Correspondence. † Laboratory and Workshop Notes.

* Correspondence. † Laboratory and Workshop Notes.

* Correspondence. † Laboratory and Workshop Notes.

* Correspondence. † Laboratory and Workshop Notes.

* Correspondence. † Laboratory and Workshop Notes.

NEW INSTRUMENTS

CAMBRIDGE: PRINTED BY W. LEWIS, M.A., AT THE UNIVERSITY PRESS